ASTRONOMY

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The First Martians

Radio Astronomy from Your Backyard

How to Be a Halley Watcher

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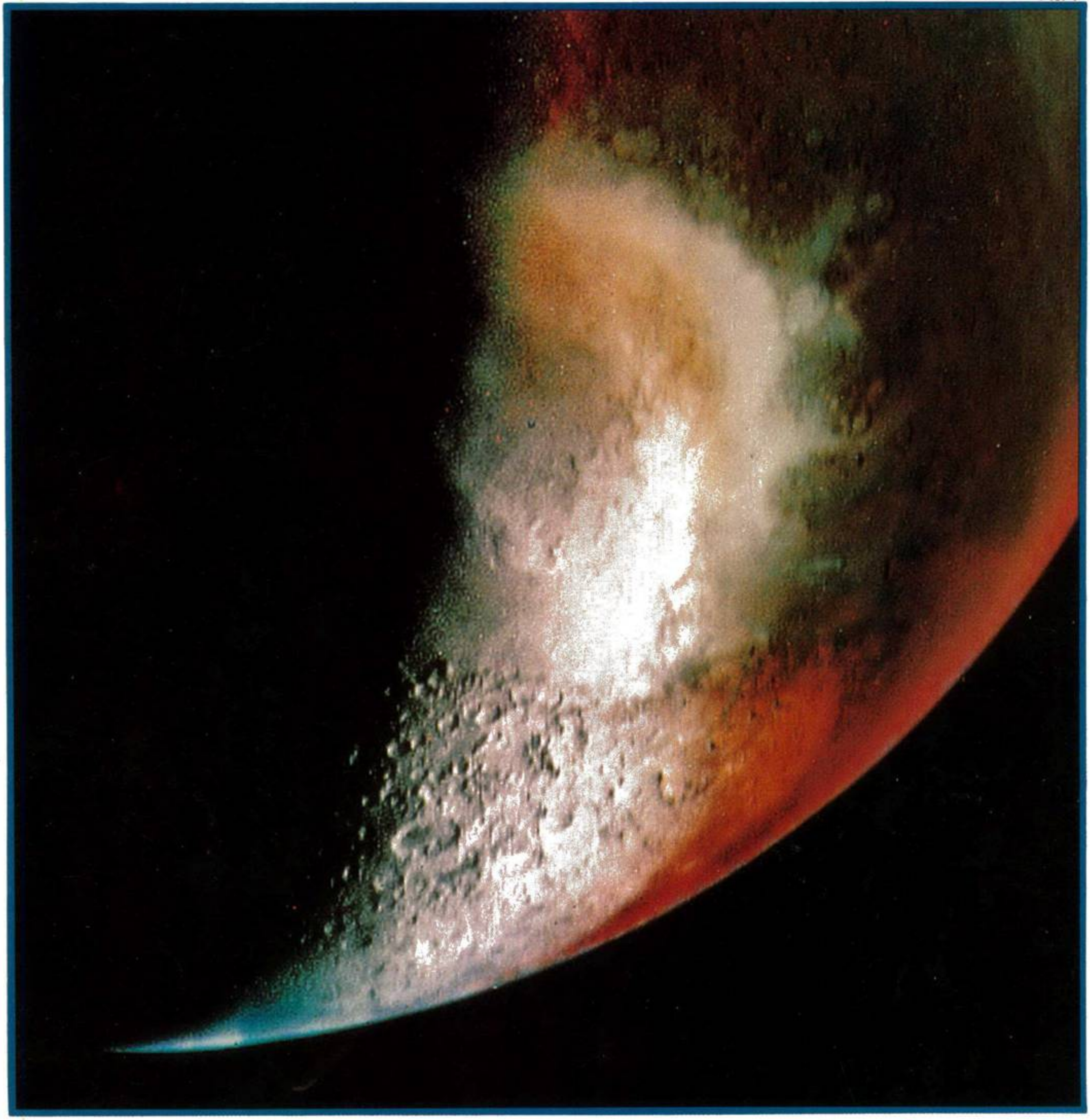

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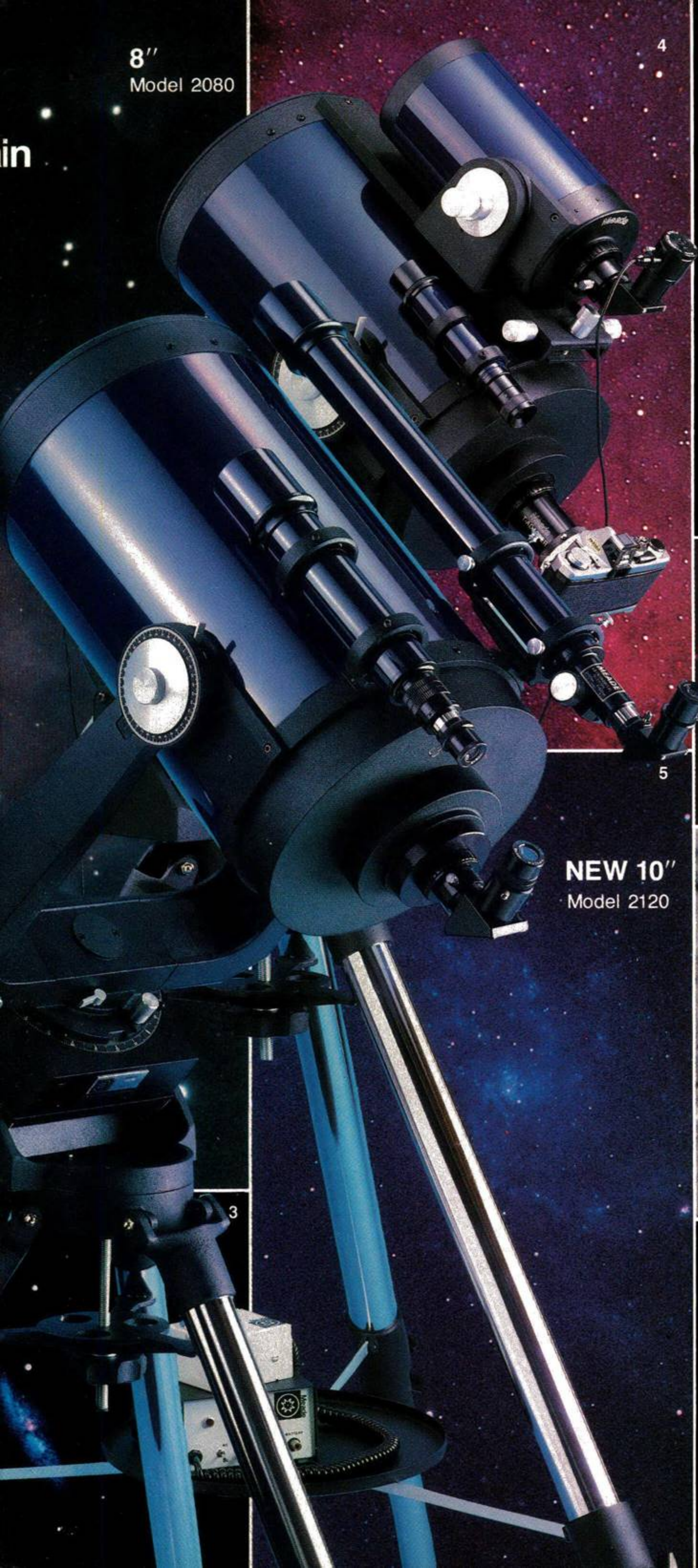

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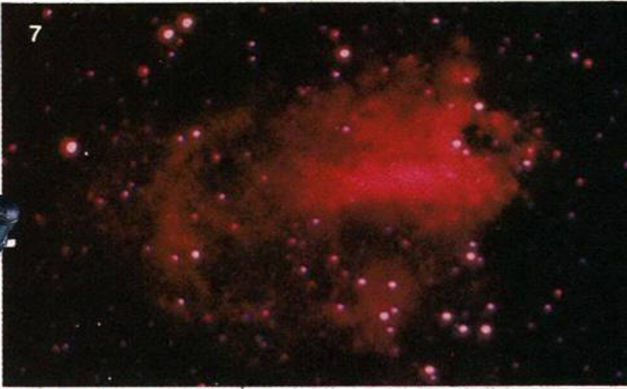

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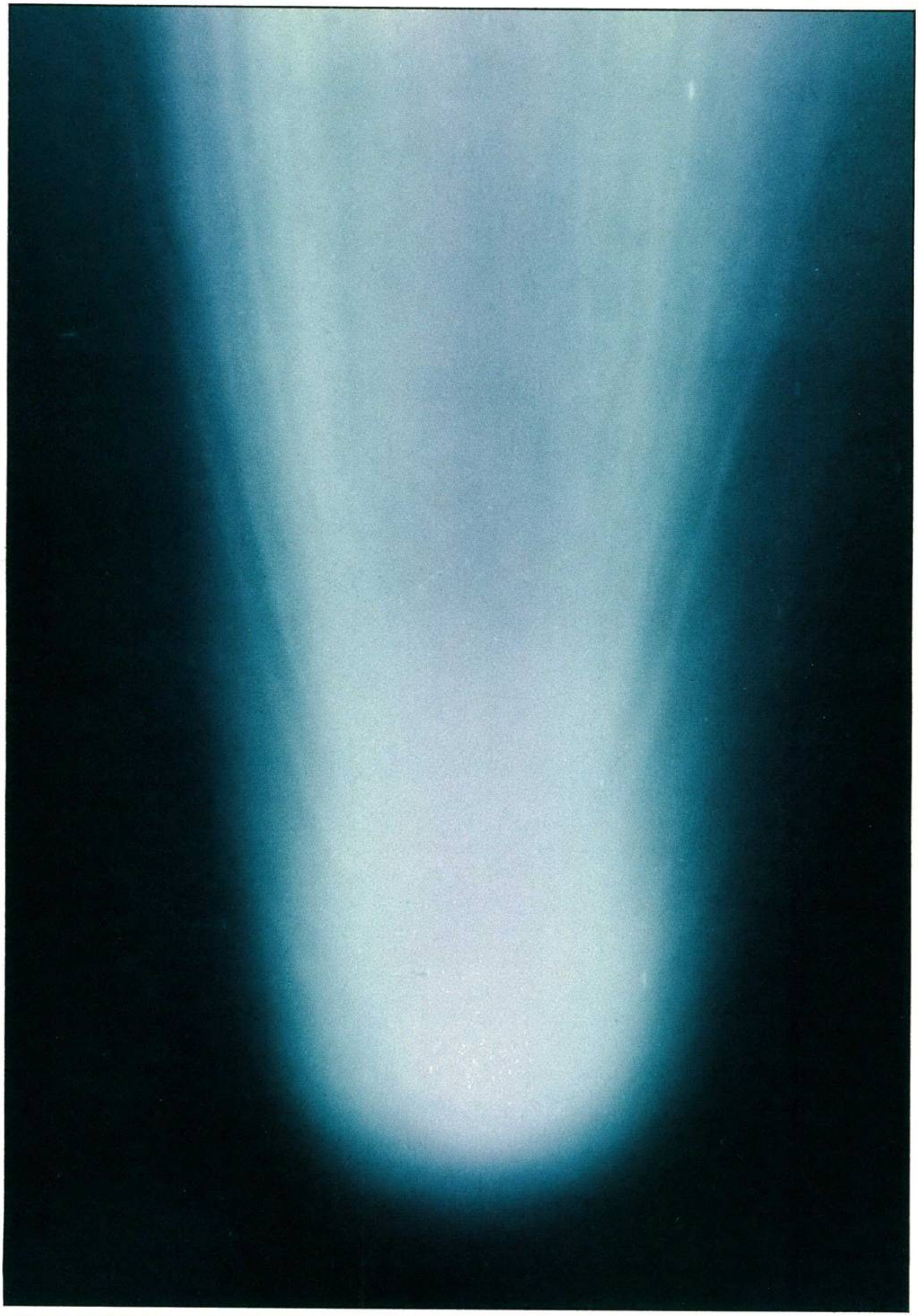
All astrophotographs shown on these pages were taken through off-the-shelf, unmodified Meade 8″ Model 2080 Schmidt-Cassegrain telescopes. For further technical details on these and many other astronomical photographs, send for your free copy of the Meade Schmidt-Cassegrain Astrophoto Brochure. (Alternately, the complete Meade 52-page General Catalog is available at $3.00 by First Class Mail and includes the Astrophoto Brochure at no additional charge.)

Key to Photographs
1, 2, 3, 5—Leo Henzl; **4, 7**—Emery Hildebrand; **6**—Paul Roques; **8**—John Sanford

1. Orion Nebula M42; exposure time 50 mins. **2.** Andromeda Galaxy M31; 60 mins. **3.** Galaxy M82; 60 mins. **4.** Milky Way in Sagittarius (50mm piggyback photo). **5.** Spiral Galaxy M33; 75 mins. **6.** Spiral Galaxy M51; 90 mins. **7.** Omega Nebula M17; 40 mins. **8.** Moon—Clavius region.



ASTRONOMY

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Cover: The next frontier for manned space exploration is unquestionably the planet Mars. Blessed with abundant natural resources, Mars holds out the promise of a second home for humankind. Our lead feature this month examines the case for manned spaceflight to the Red Planet — and it's an exciting story. Viking photo from JPL/NASA. These pages: Our second feature is on another exciting subject — the upcoming return of Halley's Comet and the plans that are afoot to make it the most studied comet in history. What's more, the story tells how anyone with even simple equipment can help out professional astronomers by joining the International Halley Watch. Mt. Wilson Observatory photo of Comet Halley.

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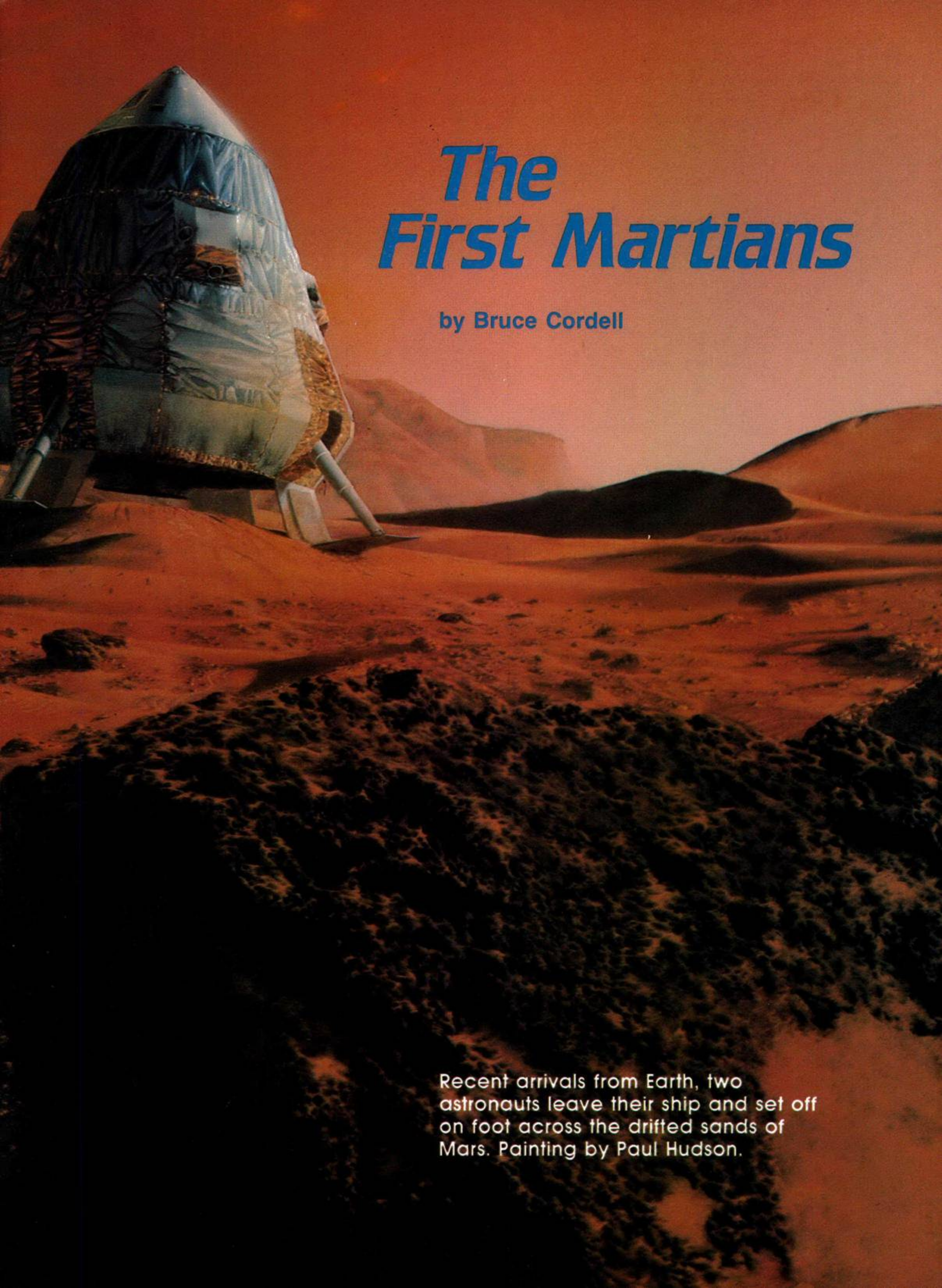
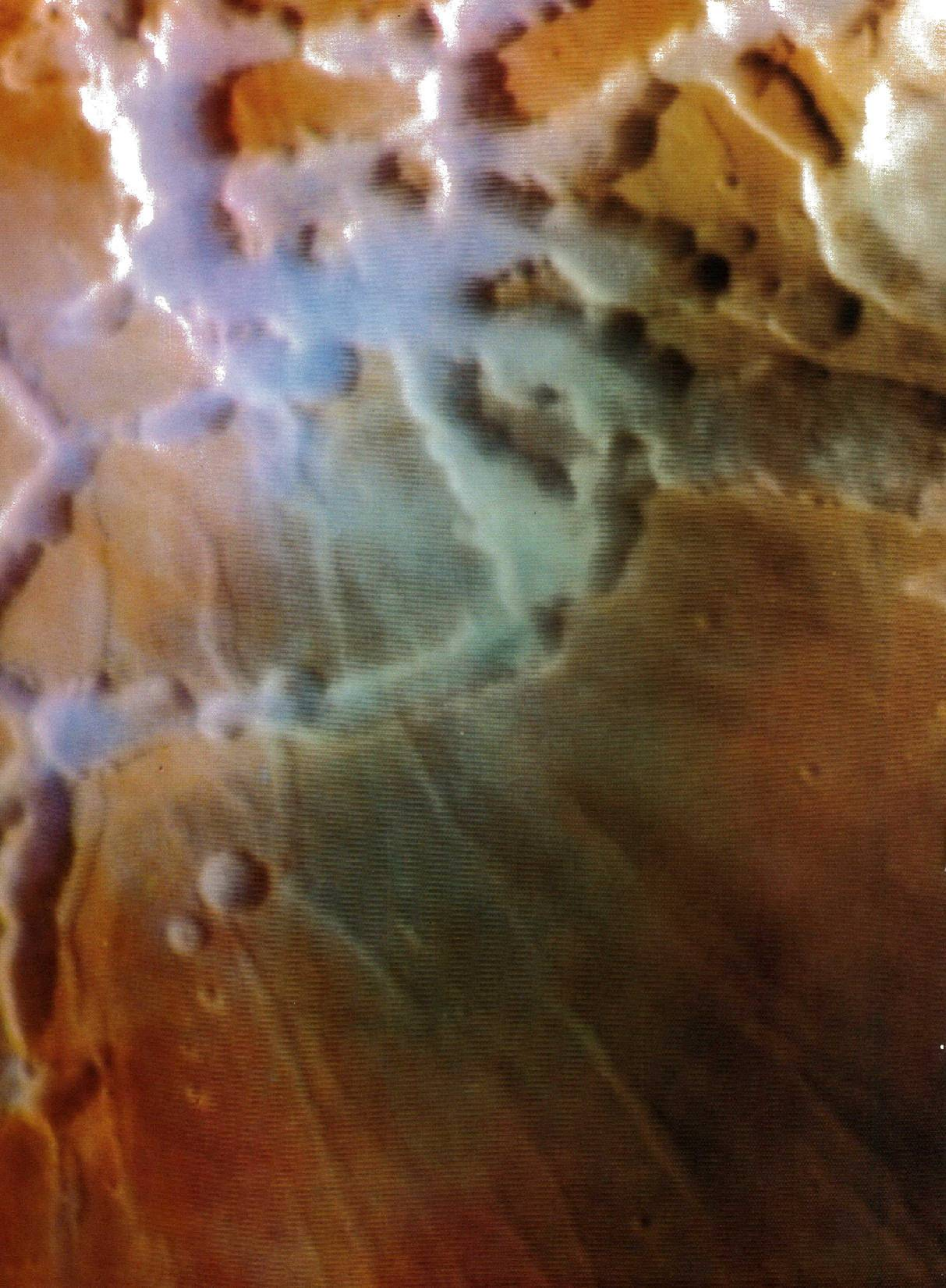
The First Martians

by Bruce Cordell



Recent arrivals from Earth, two astronauts leave their ship and set off on foot across the drifted sands of Mars. Painting by Paul Hudson.



Unimaginable scientific treasure, vast mineral and other natural resources, and breathtaking adventure await us on the Red Planet. And yet there are those who don't think this is the time for manned missions to Mars. So let's have it out — why *should* we be sending human beings to Mars?

Aside from increases in scientific knowledge, there are more mundane reasons to explore and exploit the Red Planet. In the past, space spectaculars such as Sputnik or the Apollo lunar landings have increased the prestige of the nation that accomplishes them. A manned Mars landing by the United States would be viewed by the rest of the globe as a manifestation of our ability to set and meet new challenges and as a success for democracy.

The establishment of self-sufficient research bases on Mars would be another giant step for mankind on the road toward removing industrial pollution from Earth's already crowded surface. Abundant natural resources on Mars — and later the mineral-rich asteroids — would become available to an increasingly impoverished Earth. And perhaps most importantly, the manned exploration of Mars would demonstrate to the world that the future can hold alternatives to poverty, disease, and nuclear devastation.

Yet many will still claim that, considering the extraordinary successes of Viking and other unmanned probes, as well as the expense and risks associated with manned spaceflight, we should send an automated representative of ourselves rather than the real thing. After all, robots have become extremely sophisticated, require no life support, need not return, and can be equipped with detectors vastly superior to the human eye.

While this point of view certainly contains undoubted truth, it misses two important points. The first is that, although machines excel in routine tasks like environmental sensing and the processing, transmitting, and recording of data, human beings are better at testing, assembly, maintenance, and repair of advanced instrumentation. Unexcelled in the exercise of judgement when experience and skills are needed, a trained human can select important phenomena, establish priorities, and be flexible in scheduling and scientific investigations. On Mars much of the scientific work will involve the geological, geophysical, and meteorological surveys of the planet's environment — tasks carried out best by human beings on Mars. Unmanned instrument probes work well when a survey is limited in scope; global geophysical studies need the flexibility of human control at close hand. For thoroughgoing exploration of Mars, a manned mission is likely to be more cost-effective.

There is also another aspect to the question. Lack of the human element in planetary explorations has probably helped to create a psychological void in many non-participating, but potentially supportive, individuals around the world — which may do a lot to explain the current lack of political support for manned planetary missions in the U.S. government. It is hard to see how machines alone, no matter how sophisticated, will command the necessary political support.

Significantly, no other celestial object is viewed by the public as more Earth-like and worthy of exploration than Mars. Its atmosphere, seasonal changes, and relatively abundant water indicate a planet distinctly different from hostile worlds like the Moon, Mercury, and Venus. The public already endorses manned spaceflight in the Hollywood form (e.g., *Star Wars, Star Trek, E.T.*); in addition, a lingering Lowellian view of Mars as a possible abode of alien life, and the stupendous close-up images of Mars' rubbly surface (compliments of Viking), have all suggested to many that this is a planet which *should* be explored by humans — in person.

A dominating concern for Mars settlers is locating water: the white clouds of water ice that fill the canyons in Noctis Labyrinthus offer hope that adequate supplies can be found — if not here, then elsewhere. Viking photo from JPL/NASA.

The Mars Mission: Choosing a Crew

Several months are required for a one-way trip to Mars, and this poses many hazardous unknowns for mission planners and astronauts. What types of individuals and groups are optimal? What psychological, biological, and social problems might confront a Mars-bound crew? Can humans actually survive, mentally and physically, a journey through tens of millions of miles of interplanetary space?

Although no one has ventured more than a quarter of a million miles away from Earth, the human problems inherent in a Mars mission can be anticipated at least in part by observing the effects of antarctic explorations and long-duration Earth orbit missions. Problems likely to plague aspirant Martians include isolation, confinement, exaggerated sensitivity regarding social status, lack of privacy, and weightlessness.

Several months of isolation and repetitive work could transform the first manned Mars mission into monotonous torture for the crew, possibly precipitating psychosomatic illnesses like headaches, moodiness, or depression. The Russians have discovered that cosmonauts begin to display overt hostility toward ground control after about 30 days of a long space mission. The third Skylab crew was so overwhelmed by work that they issued an edict to the ground controllers to leave them time for relaxation. Antarctic exploration personnel eventually become suspicious toward outsiders (visiting journalists, for example), but apparently repress these feelings toward each other. Such antisocial behavior among a crew 10 million miles from Earth might wreck the mission.

In an effort to avoid adverse in-flight reactions, the Russians subject potential cosmonauts to stressful parachute drills and dangerous survival tests in isolated areas. In flight, changes in work schedules, attractive and variable habitats, interesting recreation and exercise opportunities, and sufficient privacy for individuals have all helped a lot and may reduce this hazard on the Mars flight.

One problem not so easily avoided is prolonged weightlessness. The gravity-liberated heart experiences a number of degenerative effects, including occasional severe arrhythmias, which must be counteracted by vigorous physical exercise during the mission. Decalcification of the skeletal system proceeds slowly (about 0.3 percent per month), but no one yet knows how far it will proceed, and no completely effective remedy is known. Problems with interrupted circadian rhythms (24 hour day-night cycles) may produce symptoms resembling jet lag, but the flight crew could probably eliminate the difficulty by controlling the periods of artificial lighting.

Who would make an ideal Mars astronaut? Do superbly conditioned athletes or normal people best adapt to weightlessness? Unlike previous space missions, Mars astronaut crews will be selected not only for their individual attributes but for their social and group skills as well. Even the riddle of extrovert versus introvert is not as obvious as it seems, since extroverts appear to be more subject to isolation-induced withdrawal from the group. The ideal Mars astronaut crew will consist of at least seven people, both men and women, having well-specified official duties and powers, excellent scientific expertise, good social skills, and complete dedication.

The Outward Flight

Serious plans for manned missions to Mars are hardly new. Thirty years ago Wernher von Braun published a book called *The Mars Project*, which contained the first detailed engineering study for a manned landing on Mars. The grandiose scale of this plan — involving 10 ships and 70 men — was exceeded only by its price, due to its reliance on then-available technology. Moreover, it came at a bad time — the Eisenhower administration was fundamentally opposed to big space projects — and the von Braun proposal never left the drawing boards.

The years since have seen the development of large, one-shot boosters and, more importantly, the Shuttle and such sophisticated propulsion techniques as solar electric-powered ion drives. These have increased mission flexibility and decreased costs significantly. One recent proposal for a manned Mars mission for 1995 envisions using existing and soon-to-be developed Shuttle technology (i.e., the Heavy Lift and Orbital Transfer Vehicles) plus presently available electronics for communications, power, and life support. This mission features three spacecraft (two orbiters and a lander), a 20 day stay on the surface of Mars, a side mission to Phobos, and a return to Earth by means of a Venus swing-by. Expected Shuttle developments should shrink mission costs to only four times that of the unmanned Viking — a total of $4 billion.

A desire to spend more time on the surface of Mars has led to suggestions for using the solar electric propulsion system (SEPS). At present, such a drive — using mercury ions as fuel and attaining exhaust speeds six times those of chemical fuels — is capable of transporting two to four tons into Mars orbit in six to nine months. While the mercury-ion drive is essentially operational right now, the creation of an argon-fueled drive would not only triple the system's propulsive capability, but the argon known to be present in the atmosphere of Mars could make the Red Planet an important refueling station for inner solar system and/or asteroidal exploration missions. Unfortunately, budget cuts have kept SEPS earthbound.

Nuclear rocket research has a long and successful history (technically, if not politically) in the United States. A decade ago, a NASA engineer described a marvelous gas-core nuclear propulsion system capable of delivering a 50-ton command module containing five astronauts into a 300-kilometer-high martian parking orbit in only 30 days! Had work on this project, begun in the early 1960s, progressed unimpeded, it's likely that an operational gas-core engine would exist today; however, the project was terminated in 1978. Nevertheless, nuclear engines retain their potential for Mars astronauts of the early 21st century.

NASA itself has made an official study for a manned mission. Its designers assumed use of the Shuttle to deliver the spacecraft parts to low Earth orbit, orbital assembly near an already existing space station, chemical propulsion, a total crew size of five, and a round-trip time of 600 days. Total cost of the NASA Mars flight was estimated at $23 billion (in 1981 dollars). This compares interestingly with a total Apollo price tag of $63 billion and the Shuttle bill of $13 billion (both also in 1981 dollars). To put these figures in perspective, during its peak years the Mars mission would use less than one percent of the U.S. Gross National Product.

Unmanned Scout Ships First

With so much of the mission depending on conditions on Mars, unmanned probes — highly sophisticated descendants of Viking and Voyager — will be sent out long before to insure that the potential landing sites meet the engineering, scientific, and survival-related criteria. The importance of water to martian weather, climatic history, and astronaut survival makes it essential that we know how much water there is and where it is located. Therefore, a Mars Polar Orbiter (MAPO) water mapping mission, using infrared radiometers and ultraviolet spectrometers, has been advocated by University of Colorado astronomer Charles Barth. MAPO would explore the distribution of martian water resources for less than $100 million, and its low circular orbit would also present a new opportunity for detailed study of Mars' gravity and magnetic field variations.

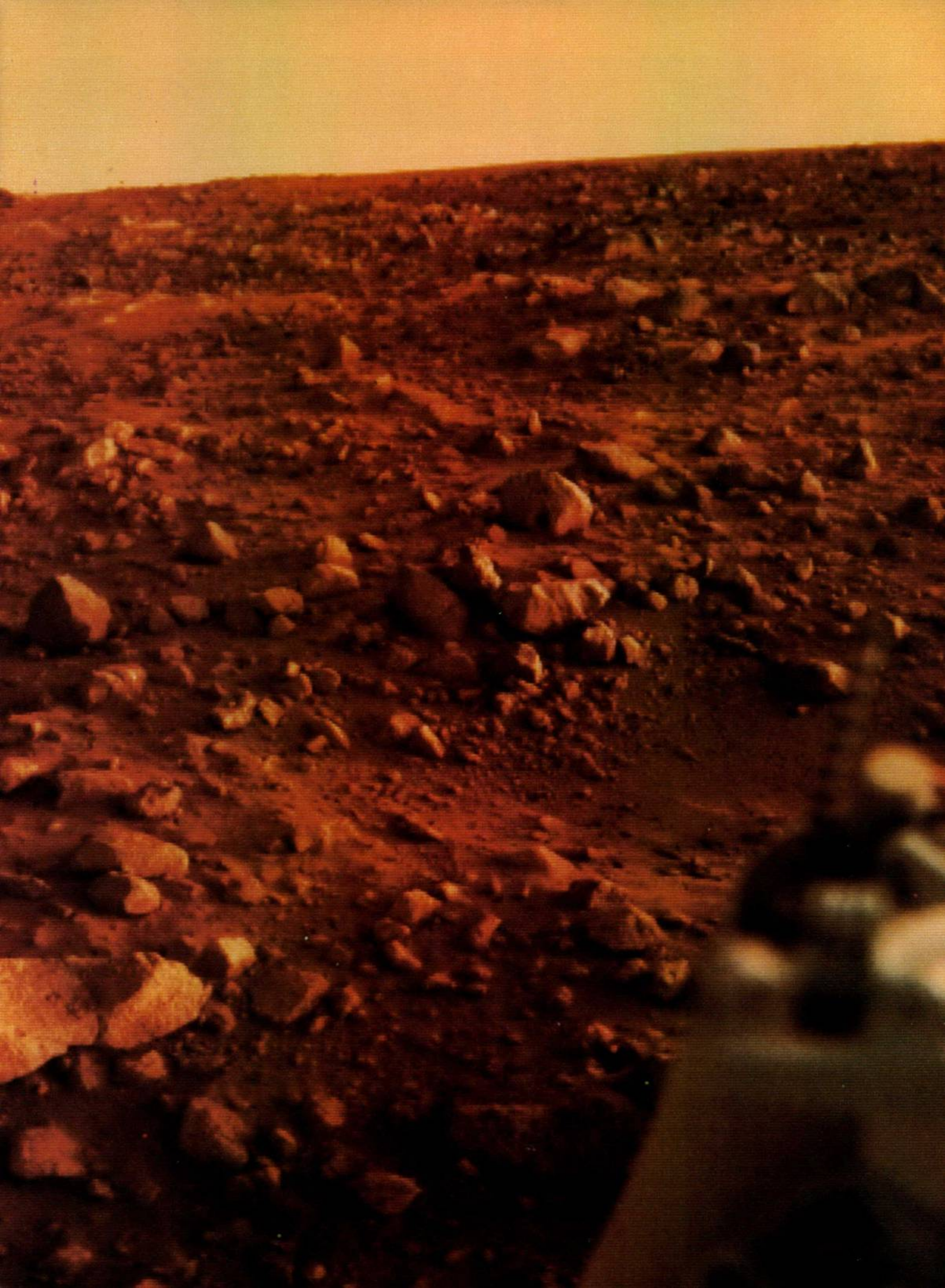
Equally tantalizing is the proposal for a geoscience MAPO that could systematically record the surface appearance, topography, and geochemical/geophysical variations across the martian globe. The European Space Agency has proposed a spacecraft (to be called "Kepler") for global exploration of Mars' environment. Monitoring the martian atmosphere's temperature, pressure, particulate matter, and ozone changes should reveal many now-obscure atmospheric secrets. The proposed orbit (at an altitude as low as 150 kilometers) would allow precision gravity analysis, while the inclusion of a radar altimeter would improve data on surface elevations.

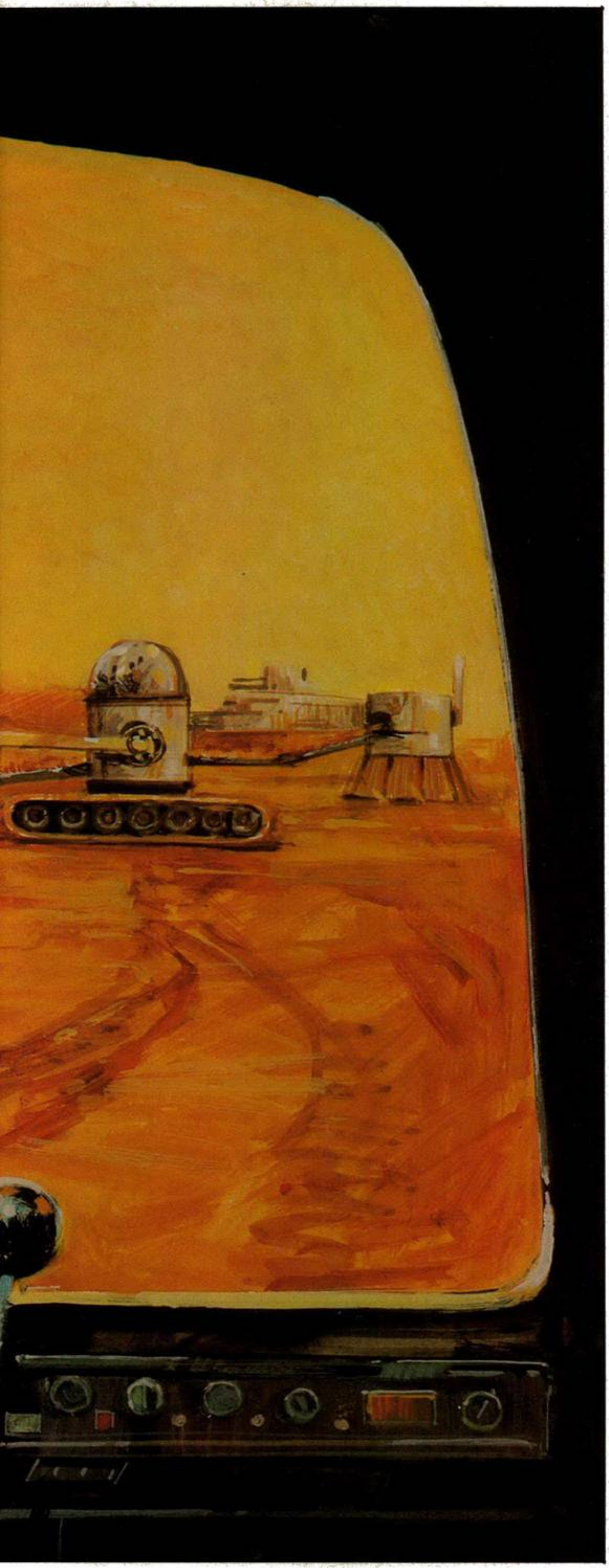
A logical extension of present capabilities would include a mobile Viking lander — a Mars Rover. Ideas for such landers range from sophisticated autonomous vehicles capable of traveling 1500 kilometers per year to the ludicrous-sounding "Mars ball probe" — a spherical wind-driven package that would literally roll across the red martian sands. A rover could carry surface sampling equipment, TV cameras, direct communications with Earth, and experiment packages to be left at selected locations.

Many Mars mission planners are intrigued by the idea of a Mars Orbiter bristling with several cylindrical penetrators, whose purpose is to survive hard landings (20,000 Gs) and deliver important scientific instrumentation. (See "The Planets or Bust," ASTRONOMY, May 1982.) Several penetrators — armed with seismometers, thermocouples, magnetometers, imagers, gamma-ray and X-ray spectrometers, and meteorological sensors — could be deployed across the martian surface to provide priceless information on the planet's interior, rock composition, weather, and surface appearance.

The ultimate unmanned Mars mission is the sample return. Detailed analyses of martian surface materials in terrestrial laboratories would tell planners what kinds of raw materials are available to future Mars explorers, and would allow an assessment of what (if any) bacteriological problems may await the astronauts. Sampling Mars' polar

Mars is a desert — an apparent wasteland. Yet in these rocks lies an abundance of minerals that may support a colony with water, air, and raw materials for a burgeoning martian industry. Viking 1 photo from JPL/NASA.





ice caps would be important because of their significance to Mars' climatic history and also because trapped materials at the poles will probably be representative of the entire planet. Investigating rock strata in the large canyons is scientifically compelling, though very demanding from an engineering standpoint.

Some Mars enthusiasts recommend the establishment of a Mars "air force" to photograph and map the geology of the surface in great detail, as well as take air samples, observe weather, and even touch down for ground samples to aid in the selection of a landing site. After it enters Mars' atmosphere, the Mars Airplane would unfold its full 70-foot wingspan. Studies indicate this propeller-driven craft could be battery powered or hydrazine fueled; the plane would be either remote-controlled or equipped with advanced terrain-following radar similar to that developed for cruise missiles today.

Fred Singer, an astronomer at the University of Virginia, has emphasized the importance of a preliminary manned mission to the tiny martian moons Phobos and Deimos. From bases on these rocky outposts, astronauts could easily direct the activities of Mars rovers, penetrators, or aircraft. This would reduce the necessity for sophisticated computers on board the exploratory craft and would eliminate long Earth-to-Mars radio delays. Detailed geochemical studies could be performed without the slightest risk to Earth of biological contamination, and the moons themselves could be examined with an eye toward using their mineral resources in the Mars base. It might also help us assess the mineral wealth of the asteroid belt since Phobos and Deimos are probably captured asteroids themselves. This "PhD proposal" (from *Ph*obos and *D*eimos) might be a prudent, if non-essential, precursor to the first manned landing.

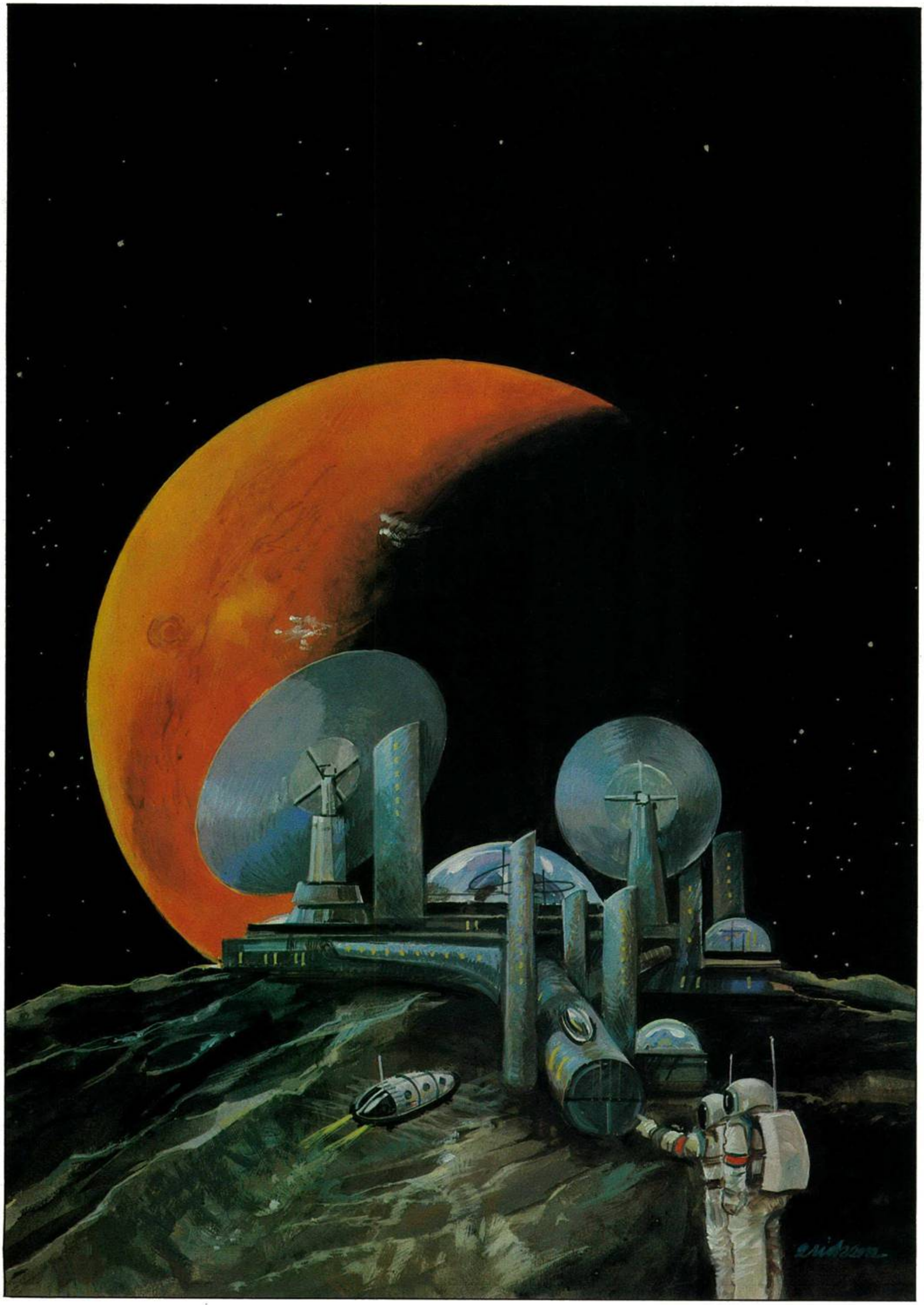
Each of these unmanned missions is technically possible today and suffers only from a lack of political will and funds. The Mars water mapper, high resolution imaging of the surface, and sample-return missions are of central importance in selecting the optimal landing sites. The PhD proposal (another potential great contributor) unfortunately carries a price tag of about half that of the manned Mars mission itself. But if we don't fly it first, we'll have to select the landing site from Earth and send unmanned supply ships to cache supplies at the landing sites before the arrival of the astronauts themselves.

The Mars Landing

The first manned landing on Mars will dwarf in importance most of the events in the entire history of human civilization. After the crew overcomes its initial excitement in stepping out onto another world, these first Martians will begin the crucial search for local supplies of water and oxygen. The ultimate goal of any extraterrestrial base — independence from Earth — is impossible without finding the necessities of life (chiefly water), as well as adequate power sources and raw materials for building an artificial ecosystem.

Mars planner T.R. Meyer of Boulder, Colorado, has suggested obtaining water, air, and other important substances by direct "mining" of the tenuous martian atmosphere. Although Mars' atmosphere is only 0.03% water, the air usually becomes saturated with water

Any settlements on Mars will need to be as self-sufficient as possible; after scientific surveys have pinpointed the necessary deposits, mining operations will begin. Painting by Barbara Ericksen.



because of the frigid temperature. Rain, however, is impossible. On a typical "balmy" (–60°C) martian evening, a cube of air 45 meters on a side will contain one kilogram of water vapor, which may be condensed by rapidly compressing the air and then cooling it to equal the surroundings. The explorers could power the process economically by using solar energy. Mars' atmosphere is thin (surface pressure is 1/150 that of Earth) and generally cloudless; thus despite the fact that strength of sunlight ranges throughout the martian year from 36% that of Earth at aphelion to 52% at perihelion, there will be ample sunlight to put to use.

Dehumidifying the atmosphere is only one source of water; thirsty Martians may also seek relief by locating subsurface ice deposits (permafrost) and liberating chemically bound water from the martian soil. Earth-based and spacecraft observations suggest that Solis Lacus and possibly other areas reach high temperatures and may even have pools of liquid water on the surface.

The explorers could obtain oxygen by solar-powered electrolysis of water, a process whose success depends on the abundance of martian moisture and the ease of extracting it. Alternatively, compressing martian air to about 75 pounds per square inch pressure will liquify its dominant component — carbon dioxide — and leave an apparently breathable residue mixture of 50% nitrogen, 30% argon, and 20% oxygen (Earth's air is 78% nitrogen and 21% oxygen). A third oxygen-mining scheme uses hydrogen gas to reduce atmospheric carbon dioxide to water and carbon monoxide; the water would be electrolyzed to yield hydrogen and oxygen. The remaining hydrogen could be recycled to reduce more atmospheric carbon dioxide.

Other well-known chemical processes can use martian atmospheric resources and solar energy to produce ammonia (a plant nutrient and power source), hydrazine (for power and rocket fuel), nitric acid (for oxygen storage), formic acid (for storage of electricity), and methane (natural gas).

Building an Ecosystem

Permanent and efficient operation of Mars bases will require that human life be maintained in a closed ecosystem containing green plants for photosynthesis and food production. This engineering task is particularly challenging because Earth's extraordinarily complex biological and biochemical cycles are only primitively understood.

Certainly one of the fundamental parts of a closed martian ecosystem will be greenhouses. P.J. Boston of the University of Colorado has investigated the idea of creating from simple materials low-pressure structures in which to grow green plants and food. The greenhouses would be constructed in small impact craters or other depressions and would resemble balloons; essentially reinforced double-walled plastic bags inflated with atmospheric carbon dioxide, the greenhouses would be kept at biologically tolerable temperatures by passive solar heating. An aluminized mylar shade could act as a blanket during the chilly nights. Viking experiments indicate that the martian soil is not toxic. If necessary, organic wastes from the base could be added.

Prior to the actual landings, crews may set up a way-station on Phobos. From here, scientists can oversee in-depth surveys carried out by remote-controlled unmanned probes. Painting by Barbara Ericksen.

Amazingly, common terrestrial plants can grow and thrive under the rather stressful conditions of a martian greenhouse. Experiments indicate that mung beans, alfalfa, and even radishes can adapt to this bizarre environment. Later generations of genetically-engineered plants may synthesize oil, gas, and other hydrocarbons. The greenhouses would also aid the new Martians by continually releasing photosynthesized oxygen, and perhaps by providing a psychological boost to any crew members suffering pangs of homesickness.

Beside meeting biological needs, a permanent Mars base must also protect its inhabitants from the harsh environment outside. The low surface pressure is barely 0.7% that of Earth. Large daily and seasonal temperature changes are the rule; highs of +22° C and lows of –123° C have to be planned for. Sub-arctic conditions generally prevail. The planet's wispy atmosphere and lack of a strong, shielding magnetosphere conspire to increase the threats from meteors, solar ultraviolet rays, and cosmic radiation. Burying the habitable parts of the base underground would substantially lessen these problems and ease structural and insulation aspects of shelter construction. For surface activities, the martian day of 24 hours 37 minutes is close enough to Earth's not to upset the explorers' circadian rhythms. The low gravity — a third of Earth's — will be a delight.

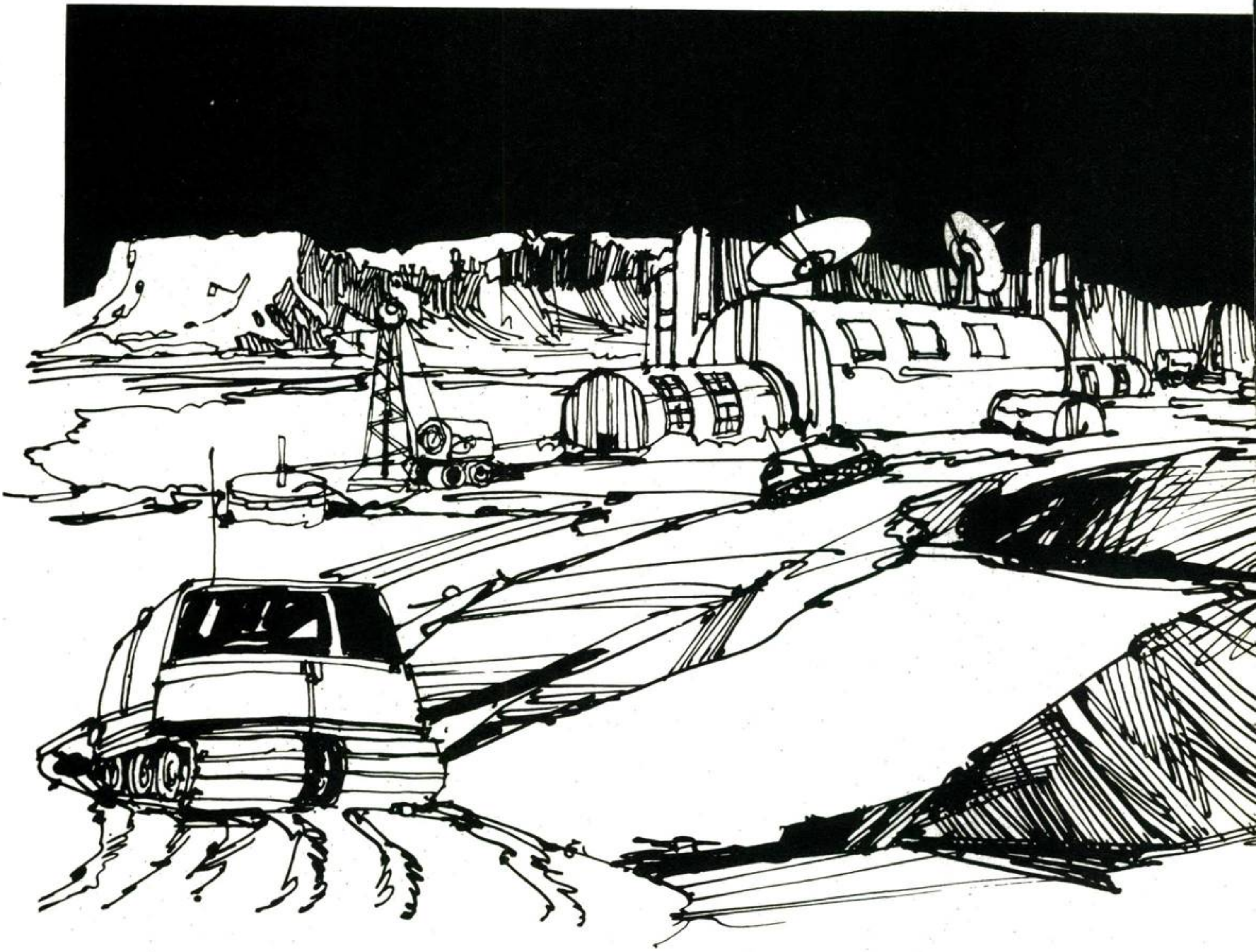
The Mars Base

Regardless of where it is located, the base will probably consist of at least five sections: *living quarters* containing sleeping, cooking, eating, and recreation facilities; *scientific labs* with space and instrumentation for geoscience, physics, chemistry, biology, meteorology, astronomy, engineering/materials science, psychology, and other activities; an *operations center* responsible for communications (surface and satellite), traffic control, and general administration and coordination of all base activities; *environmental control* responsible for operations, maintenance, and expansion of air conditioning, heating, power, oxygen and water production, and waste processing; and finally a *hardware storage and maintenance center* responsible for the computers, machine shop, electronics, vehicles, rockets, and construction of the Mars shelter.

The initial crew might number less than a dozen, but this would climb to hundreds in several years once the base had established itself. Power for the bases will be provided by the Sun, possibly aided by giant mirrors in orbit. And when the Mars base becomes a reality, around the year 2000, nuclear fusion engineering may have reached the stage where it is practicable.

For exploring outside the base buildings, a space suit will be necessary to protect against the low atmospheric pressure and the fearsome cold. But because such a suit will be cumbersome and tiring to wear, anyone traveling more than a short distance away from the base will use a rover vehicle similar to those used by Apollo astronauts on the Moon. More ambitious expeditions spanning hundreds or thousands of kilometers will probably use a pressurized version of the Sno-Cat vehicles common in Antarctica. For extremely long trips, it might even be possible to travel in a manned version of the Mars Airplane.

On a typical day, the activities at an advanced Mars base might resemble these: operations is frantically preparing orientation materials and quarters for the new shift due to arrive soon from Earth. Environmental control



electronically senses a leak in one of the greenhouses (due to the impact of a small meteor) and dispatches a repair crew. In the science center, geophysicists use a satellite relay to direct an exploration crew hunting for new groundwater deposits. Most of the bioscience staff is visiting Earth to receive international awards for their recent discovery of life on Mars — indigenous microorganisms found in the Solis Lacus pool. And, in the video sensation room, off-duty Martians devour supercorn and prepare to immerse themselves in a showing of the holographic ultra-movie, *Star Trek VIII.*

Toward Independence

What we'll actually find on Mars when we have explored it fully is impossible to say, but we can guess at the bonanza that awaits us. Perhaps the most important fact about Mars is that, unlike the Moon, it contains all the raw materials necessary to make a base self-sufficient. Viking chemical analyses of the soil — which determined elemental abundances but not precise mineral compositions — indicate that substances available at the surface include water ice, salts (sulfates and chlorides), nitrogen and carbon compounds, and important metallic elements such as iron, titanium, aluminum, magnesium, and silicon. Less abundant, but no less crucial, elements include zinc, mercury, and lead.

These and other materials can be used to construct the Mars base and lay the foundation for a thriving manufacturing industry. For example, oxygen, silicon, calcium, and carbon are the constituents of construction materials like plaster of paris and cement, which can be reinforced by steel made from martian iron. Agriculture can be given a boost with fertilizers composed of potassium and nitrogen from the local environment, glass and plastics are a cinch with abundant silicon and hydrogen, and sulfur and chlorine have great industrial and chemical versatility. Although not confirmed, Viking chemical analyses and surface images strongly suggest the presence of basalt-like rocks, which have potential applications as building materials, furniture, insulation, and even cloth. Interestingly, hydrogen peroxide may play a key role in the development of a martian civilization because it is a convenient source of hydrogen, water, oxygen, and energy. The physical and chemical processes necessary to transform native martian raw materials into industrial products are already in use or will be in the foreseeable future.

As they explore the planet, the Martians will have three objectives in mind: 1) identify the important planetary processes on Mars, ascertain its planetary

Mars Base
Ericksen

Drawing by Barbara Ericksen.

evolutionary history, and apply these new concepts toward an eventual understanding and wise use of Earth's natural environment and resources; 2) firmly settle the question of extraterrestrial life on Mars; and 3) begin the global inventory of martian water, mineral, and other natural resources with significant economic, industrial, and interplanetary trade potential.

One fundamental question concerns martian climate and its variations over the last 4.5 billion years. The lack of present-day martian oceans suggests a simpler meteorological system than Earth's, and Mars' 24-hour spin guarantees that Coriolis and other rotation effects are Earth-like. But martian weather systems are complicated by seasonal water and carbon dioxide variations. Mars also has lofty mountains that will disturb global wind patterns. A detailed study of this tenuous yet complicated atmosphere will provide valuable meteorological insights that will ultimately contribute to an improved understanding of weather on Earth. At certain times, voluminous dust clouds ascend into the martian air and shroud the planet completely for weeks on end. Detailed observations of the physics of these global dust storms may illuminate the nature of terrestrial hurricanes and other large, destructive weather systems.

At present, Mars is a global arctic wasteland, but evidence suggests this has not always been the case. Even one core sample of polar ice would tell us much about the history of the martian climate. If Mars was Earth-like in its distant past, we need to know — in detail — what happened to it.

Our ignorance of the interior of Mars is nearly total. Does Mars have an Earth-like core? Is it liquid or frozen? An array of seismometers could pinpoint these hidden secrets in weeks. Does Mars have a magnetosphere? Are the solar system's largest known volcanoes still active?

We must probe into the geologic structure and history of Mars. What rock types litter the surface? How old are the towering volcanoes and ancient cratered terrain? Geologic mapping and rock sampling and analysis are ideal chores for martian astronauts. An accurate martian time scale is possible using absolute radioactive dating of surface rocks. Geophysical surveys will illuminate the subsurface rock structures.

Investigations on Mars will provide insights into fundamental questions of planetary origin and evolution. For example, what roles do size and solar distance play in the development of planets? What are the important differences and similarities between Mars and Earth? What are the long-term futures of both?

The scientific exploration of Mars will thus serve two ends: enriching our knowledge of Earth and fostering the development of a sound economy on which, ultimately, a successful martian colony must depend. After crews exploit the locality of the landing site for biological necessities and base construction materials, the important question of global resources will arise. Does Mars have concentrated deposits of important metals and minerals? On Earth the formation of ore bodies proceeds in conjunction with hydrothermal processes, volcanism, and plate tectonics. While it appears that continental drift never occurred on Mars, volcanoes and water *are* present — suggesting that certain types of ore-concentrating processes may have occurred. Without knowing the geologic history of Mars, our search for rich mineral deposits would be haphazard at best.

Looking even farther into the future, it seems inevitable that these tiny bases will eventually foster a flourishing culture. People born on Mars will be intrigued by the idea of a trip to Earth. Mars will become a refueling and rest stop for space-faring voyagers outward bound for the mineral-rich asteroid belt. Lightweight ships assembled in orbit from precious metals mined on Mars could use the wind from the Sun to sail to Earth and its orbital space colonies.

Giant mirrors in Mars orbit will concentrate sunlight on Mars' icy polar caps, releasing carbon dioxide *and* water to restore the long-locked-away elements of the atmosphere. Green plants will photosynthesize the carbon dioxide, releasing breathable oxygen and taming the exotic Martian environment. Humans will then be able to stroll — unprotected — across the ruddy sands of Mars.

For the first time in the history of mankind, a trip to Mars and manned bases on its surface are technically feasible. How long will it be before the manned exploration of Mars becomes feasible — politically?

Bruce M. Cordell's most recent article for ASTRONOMY, "A Tantalizing Look at the Shape of Venus," appeared in the September 1982 issue. He is a planetary scientist and geophysicist at California State College, Bakersfield. He aspires to be a Martian.

HALLEY WATCH '86

by Stephen J. Edberg

Comet fever is growing. Last October, after many months of fruitless searches, astronomers using the 200-inch Hale telescope recovered The Comet — the one *everyone* has heard about. Last seen when William Howard Taft was President and Model Ts were putt-putting along America's roads, Halley's Comet is coming back, bringing with it a great opportunity for professional and backyard astronomers alike. By the time the comet swings around the Sun and returns to the deep-freeze of the outer solar system, it will be the most thoroughly studied comet in history.

To ensure that this once-in-a-lifetime opportunity isn't wasted, astronomers have established a program, called the International Halley Watch (IHW), to coordinate data collected by observers the world over. The Halley Watch's antecedents date back to the 1890s when astronomer E.E. Barnard proposed an observers' network for the then-upcoming 1910 apparition. But on this return an exciting new dimension has been added — over the past 76 years the average backyard telescope has grown in size and sophistication to the point where it is nearly as good as most professional installations were at the turn of the century. Anyone with a home observatory will be very well equipped indeed for the coming event.

Halley's Comet is big and bright, and one of its most fortunate aspects is its highly predictable path. While there are many comets with equally predictable returns, most suffer from being small and faint, and most lack cometary activity. The rare spectacular comet — one that shows a magnificient tail, jets, rays, halos, and envelopes — usually arrives unexpectedly and is gone, essentially forever, before a coordinated study can be organized.

Comet Halley is different. A member of the short-period class of comets — those having orbital periods under 200 years — its 76-year orbit has been very well studied. And best of all, unlike most of its short-period cousins, it exhibits virtually every type of cometary phenomenon observable. Halley's return will attract the attention of a horde of scientific instruments working from the ground, aircraft, balloons, sounding rockets, manned and unmanned Earth-orbiting spacecraft, and spacecraft on flyby trajectories.

Organizers of the Halley Watch have established seven categories of study according to observational technique. Astronomers who use similar instruments are setting up teams to form a round-the-world network of observers so that someone is monitoring the comet at all times. In addition, to tackle problems that require the concentrated focus of all the instrumental techniques, special days have been designated for coordinated observations by everyone.

Let's examine what methods the professional Halley Watchers will use. Then we'll look at the ways you — as an amateur astronomer — can pitch in to help.

Astrometry: The science of making precise measurements of Comet Halley's position against the background stars yields data necessary to compute a definitive orbit for this apparition. Without an accurate orbit, spacecraft navigators would have a difficult time directing their flyby spacecraft where they can do the most good. Secondarily, orbital data can reveal a lot about the physical properties of a comet. For example, as the comet nears the Sun it heats up and streams out a tail millions of kilometers long. Solar heat also causes the nucleus to squirt out little jets of gas that alter the comet's mass and give it tiny nudges that distort its smooth orbital course. If we track how much the comet deviates from an ideal path, we can begin to model the processes that operate in the comet's nucleus.

Infrared Spectroscopy and Radiometry: Observing at wavelengths longer than visible light, infrared studies of Halley should provide data

Two Halley-watchers on the morning of April 1, 1986, observe the comet as it passes through the constellation Sagittarius. Painting by Thomas L. Hunt.

What Is a Comet?

Over 30 years ago astronomer Fred Whipple developed what has since become the standard model for a comet — a dusty "snowball" only a few kilometers in diameter. The snowball is probably a mixture of frozen gases — mostly water in the older comets, with some carbon dioxide, ammonia, and perhaps methane and other carbon- and sulfur-based compounds. The dust appears to be primarily graphite, magnetite, and silicates.

The snowball is more properly termed the comet's nucleus; it is the source for all of a comet's phenomena. As the nucleus falls in toward perihelion — its closest approach to the Sun — it gets warmer and the volatile frozen gases begin to *sublimate* — change directly from a solid to a gas. The outflowing gas, carrying dust released by the sublimating ices, forms a coma around the nucleus. Together, the coma and nucleus are called the head of the comet. No one has yet seen a comet's nucleus directly — even the best photos reveal only an unresolved point of light mistily hidden in the glow of the coma.

The Sun does more to a comet than just turn nucleus material into gas: inside of about the orbit of Mars, the solar wind is strong enough to drive the dust particles out of the coma directly away from the Sun. This forms a dust tail. At the same time, solar ultraviolet radiation ionizes the molecules in the gas and gives them an electric charge. The magnetic field of the solar wind catches these ions and drags them along with it on its rush away from the Sun. The result is an ion tail. When spectra are taken of light from the dust tail, it turns out to be essentially unaltered sunlight — dust tails shine by reflection. But spectra of the ion tail show emission lines characteristic of charged elements and molecules — ion tails shine by fluorescence. In the case of Halley, the two tails usually appear as one because the geometry of Halley's orbit merges them in our line of sight.

As you might expect, the peak of cometary activity usually occurs when the comet is closest to the Sun. After perihelion, as the comet recedes from the Sun, its two tails shrink and disappear. Soon thereafter, the coma also disappears and finally only the cold, bare nucleus is left to coast outward toward aphelion in the depths of the solar system.

Observing Halley's Comet

As Halley's Comet becomes more and more accessible to amateur-size instruments, the anticipation of its arrival will certainly grow. But unfortunately, this apparition offers the worst circumstances for viewing that the comet has had in over 2,000 years. Observers who are prepared will enjoy Halley, but most members of the general public are probably due for a disappointment.

In July 1985 the comet will become visible at magnitude 14 in large (12-inch

or bigger) backyard telescopes, but will be too close to the Sun to be seen. By August it will appear in the predawn morning sky; the coma will be visible, but it's unlikely that you'll see a tail. Over the following few months, the comet moves slowly toward the west and brightens at a rate of almost one magnitude per month. It comes into the reach of small telescopes and binoculars by the end of October 1985 and will pass a few degrees south of the Pleiades star cluster in mid-November. Its first close approach to Earth occurs on November 27th at a distance of 0.62 AU (about 92 million kilometers). At this time Comet Halley will be easily visible in binoculars in the evening sky, but any tail it may have developed will be short and might be detectable only with long-exposure photographs.

Throughout December 1985 the comet will slowly increase in brightness and move southward, reaching sixth magnitude as it crosses the celestial equator just before Christmas. It will be a fourth-magnitude object during January as it appears to plunge into the western horizon, closer and closer to sunset each night, on its rush toward perihelion on February 9, 1986.

The comet will be invisible from Earth for the month of February, but when it emerges from the Sun's glare into the morning sky in early March, the stage will be set for the best view of the entire apparition. When the flyby spacecraft encounters occur during the second week of March, the comet will be rising higher in the morning sky before sunrise. At the end of March and during early April, the comet will be traversing the Milky Way in the star-cluttered regions of Sagittarius and Scorpius — to make what will surely be an unforgettable sight.

After perihelion, Halley will gradually brighten again to fourth magnitude and will probably develop a visible tail about 25° long during the first half of April. It is closest to Earth on April 11, 1986, at a distance of 0.42 AU (about 63 million km). It should then be a glorious sight, quite high in the sky to observers in the southern hemisphere; northern observers will see it low on the horizon — or even lose sight of it below the horizon — for one to two weeks.

Mt. Wilson Observatory photo.

During the last half of April the comet passes opposition and moves into the evening sky again. Seen now from both hemispheres, it will fade to sixth magnitude. As the weeks pass and the comet fades, larger and larger telescopes will be needed to follow the comet as it heads on its course back to the outer solar system.

about the nature of dust in a comet, the types of frozen gases in its nucleus, and what produces the comet's coma and tail. They will also help scientists understand something of a comet's chemistry and how it relates to the chemistry of other solar-system bodies we have studied.

Large-Scale Phenomena: Wide-angle photographs with Schmidt cameras and other instruments will supply valuable information on Halley's tail, while time-sequence studies of tail activity will provide data on how the solar wind and cometary tail interact. Several problems hinge on the way instabilities in the ion tail form and are perpetuated; photographs will help discriminate between the models currently proposed. The photos will also aid in studying how the comet's dust tail evolves.

Near-Nucleus Studies: Despite decades of observations, the exact nature of a comet's nucleus remains a mystery. By the time it has moved sufficiently close to us to be discerned in detail, a typical nucleus has been heated enough to be enshrouded in a haze of gas. Nevertheless, researchers will use images obtained with long focal-length telescopes and electronic and photographic cameras to peer into the structure of Comet Halley's nucleus and investigate its thermophysical properties, spin-axis orientation, and rotation period.

Photometry and Polarimetry: Measuring the comet's light at certain wavelengths will give information on how efficiently a comet produces gas and dust, differences that may exist between pre- and post-perihelion rates of production, the vaporization process, and the chemical reactions that have been observed to produce molecules in the comet. Measurements of the extent to which its light (both reflected and fluorescent) is polarized will yield information on the sizes of dust particles. Observing what happens to starlight when the comet passes in front of a star will permit astronomers to determine the amount of material along the line of sight.

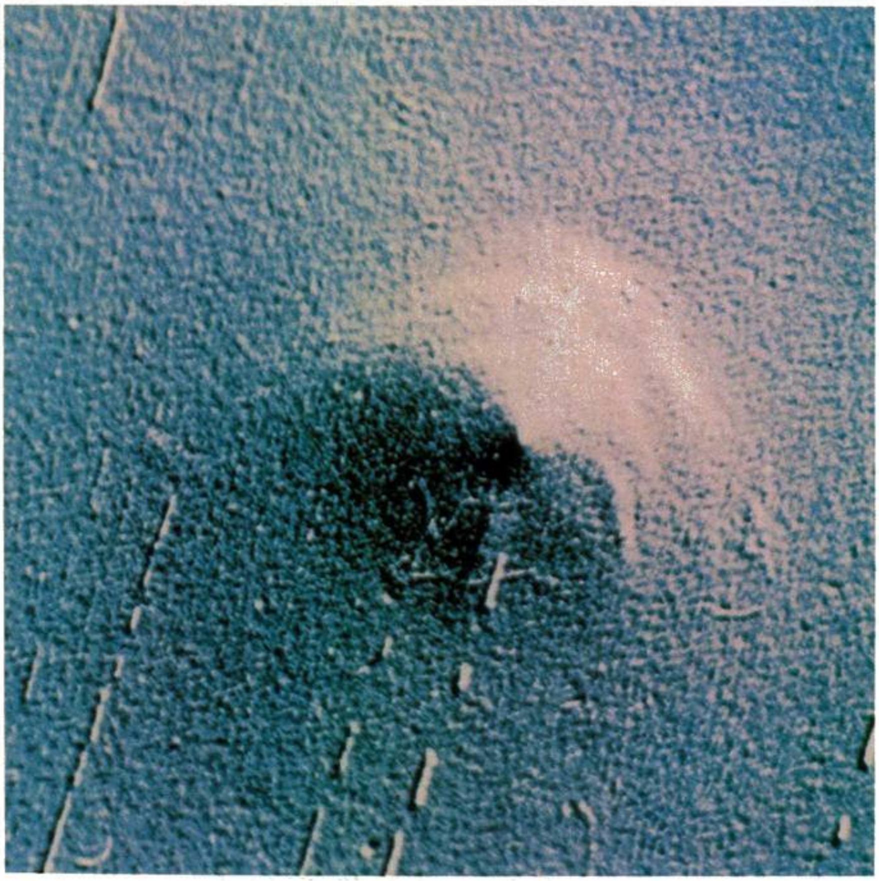
Radio Science: Radio observations of molecules in the comet can supply additional details of chemical and physical processes occurring there. Radio continuum studies may reveal more details on the nature and composition of the dust in the comet. They may also tell us something about the plasma processes involved in the interaction of the solar wind and the comet's ion tail. Radar studies — which may not be successful since they are at the extreme limits of present-day technology — are designed to yield definitive information on the nucleus, including its size, rotation rate, and surface structure.

Spectroscopy and Spectrophotometry: High-resolution spectroscopic observations of Halley's Comet made over a great range of distance from the Sun should help identify new chemical compounds in the comet. They will also yield information on the production rates and abundances of various compounds and the expansion velocity of the coma that envelops the nucleus.

If that's what the professionals will be doing, where do you and your telescope fit in? The Halley Watch wants observations from backyard astronomers to make its archives more complete. Amateurs are expected to take over in fields where professionals are no longer making observations — and also whenever weather, geographical location, or limitations on telescope time and equipment curtail professional observations. Generous enthusiasm, coupled with an ability to devote many unpaid hours at the eyepiece, makes the backyard observer a unique and important part of the International Halley Watch team.

Whatever equipment you may have — telescopes (large or small), binoculars, cameras, computers, even your naked eye — you can contribute to any or all of some six areas of comet studies. If you're interested in participating and willing to stick with it, you are welcome to join IHW. The IHW Amateur Observer's Manual (see opposite) provides detailed instructions on how to make good scientific observations.

Visual Observations: From ancient times until relatively recently, Comet Halley was observed mainly with the naked eye. Telescopes were employed starting with the apparition of 1682, and photography with that of 1910. Although visual observations were still important at the turn of the century, professional astronomers have long since abandoned them. Backyard observers thus have the field to themselves. Their observations will be directly comparable to those made at the last return — a valuable



Based on a 1910 photo, this image was specially processed to reveal structural details in the coma. Helwan Observatory photo; image processing by D.A. Klingelsmith, GSFC.

way of correlating present-day observations with how the comet appeared 76 years before.

You can make visual magnitude estimates and measurement of the coma's diameter using a telescope, binoculars, or even the naked eye. Careful drawings, especially of the head of the comet, will be useful in studies to determine the rotation rate and axis direction of Halley's nucleus.

Photography: Today's photographic equipment and films are far better than anything available in 1910; superb results are now routine. Color and black and white photos of Comet Halley will be valuable to the Halley Watch archives, but black and white negatives will be especially useful since they can be analyzed more easily.

Three types of cometary photographs are desirable: wide, moderate, and narrow-angle. You can take a wide-angle photograph that shows the whole comet using a typical 35 mm camera fitted with a 50 mm lens. Moderate-angle photographs with fields-of-view of 6° to 10° will supplement the wide-angle photos. High-resolution, narrow-angle photographs taken with focal lengths of 2,500 mm or more will supplement electronic and photographic images obtained by professionals studying the comet's nuclear region.

Astrometry: Accurate positional measurements of comets can be made by amateur astronomers — important because a good orbit must be calculated at this appearance. High-quality positions of Halley obtained by amateurs will be combined with professional astrometric measurements to compute and update Halley's orbit.

Spectroscopic Observations: Good quality diffraction gratings, prisms, and even complete spectroscopes have come on the commercial market — thus dedicated backyard observers can build objective, non-objective, and slitless spectrographs to record Comet Halley's spectrum on film. These low-dispersion comet spectra will supplement the high-dispersion spectra obtained by professionals.

Photoelectric Photometry: Although photoelectric photometry was attempted on the comet in 1910, the technique was then too primitive for

To see the comet best, you'll need a location with dark skies, well away from light-polluted cities. For observers in the northern hemisphere, a low and uncluttered southern horizon will be helpful, but a trip to temperate latitudes in the southern hemisphere will really show the comet at its best.

Any instrument — including the naked eye — will show you the comet during at least part of its visit. But since it is fairly faint, plan to give yourself at least 20 minutes to let your eyes adapt to the dark. For casual observations a pair of 7 x 50 or 11 x 80 binoculars will provide good views.

A telescope will let you view the comet at many different magnifications. Probably the best all-around scope is a Newtonian reflector with optics in the f/6 to f/8 range. Newtonians with fast focal ratios are better for wide-angle views and are more likely to show the faint, outermost portions of the comet. Slow, long f/ratio instruments like refractors, Cassegrains, or Schmidt-Cassegrains are best for high magnification, detailed studies. And of course, the bigger the scope you have, the longer you'll be able to track the comet.

For taking pictures, any camera whose shutter can be left open for a few minutes, supported by a rigid tripod, will record the comet. You should load it with fast film. Attaching the camera to a clock-driven telescope piggyback-style allows you to record views without streaked images. Used through the telescope, your camera can record elusive details in the coma.

In short, with a little preparation, this apparition of Halley's Comet will be a memorable one — and besides, unless you're very young, this is the only Halley return you'll ever see!

How to Get Involved, or: Do-It-Yourself Halley-Watching

If you're interested in joining the International Halley Watch, send a request for information to:

International Halley Watch
Jet Propulsion Laboratory
Mailstop T-1166
4800 Oak Grove Drive
Pasadena, CA 91109

You'll receive an information sheet with instructions on how to get started. You will probably want a copy of the IHW *Amateur Observer's Manual* to learn observational techniques. The manual contains an observing form that identifies you as a participant and is a survey of your observational interests, the equipment you plan to use, and where you use it.

There are many available books and guides to get you oriented (see box on page 22). You should begin observing comets now — the observations call for regular practice and, at times, tenacity. Often, high-quality scientific observations require tedious techniques; it pays to know what you are doing well in

advance! The skills you develop now will help future users of the Halley Watch archives reap the benefits of your observations.

You should also get going on meteor-watching immediately. While neither the Eta Aquarids nor the Orionids are expected to show increased activity in the next year or two, such predictions are often incorrect — and in any case, it's important to establish a "baseline" for these showers so that you can put your observations in context at the time of return.

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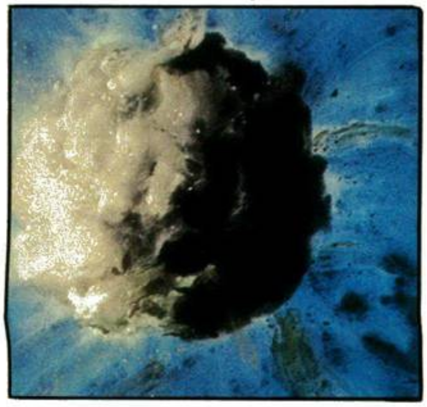
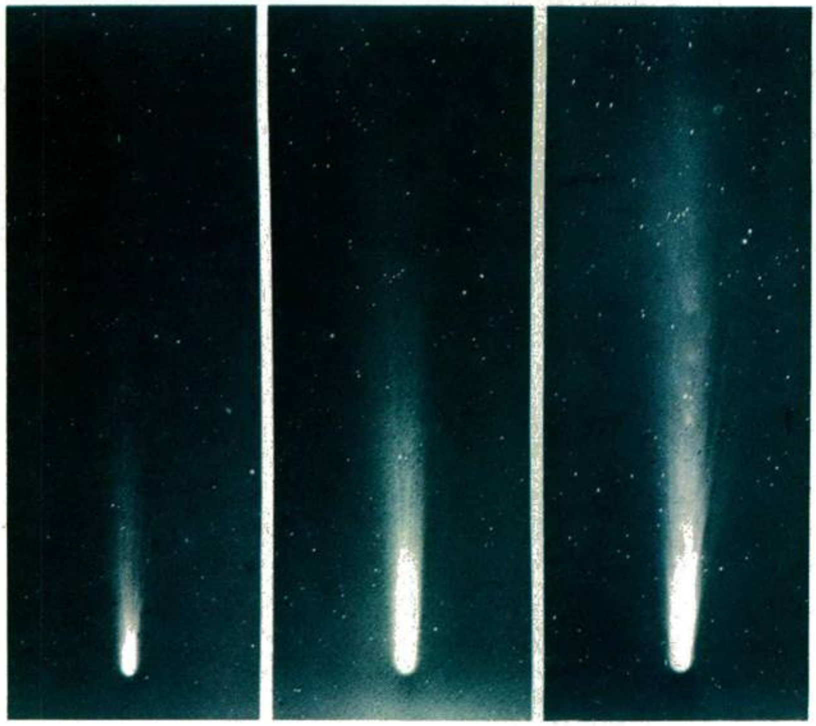
Artist's conception of nucleus.



NASA



Three stages of the growth of the comet's tail: these photos were taken on (left to right) April 27, April 30, and May 2, 1910. Mt. Wilson Observatory photos.

good results. The years since, of course, have seen the maturation of photometry into a powerful analytical tool. With good photoelectric photometers now appearing on the hobbyist market, anyone equipped with such an instrument can make valuable contributions — and with a special set of cometary filters, you can estimate coma magnitudes using different-size diaphragms.

During Halley's closest approaches to Earth, the small image scales of fast f/ratio backyard telescopes will be useful for measuring the light of the whole coma; the high-magnification, long focal-length professional instruments can record only small portions of it. Also useful are carefully timed observations of variations in intensity of the coma or the comet's central condensation, as are intensity profiles obtained by scanning across the coma or tail. Finally, photometry of a star while it undergoes a transit or occultation by the coma or tail has been done for the first time only recently — so here's a new field with many discoveries waiting to be made in it.

Meteor Observations: Since few professional astronomers are actively involved in meteor observations, backyard observers now contribute the bulk of them. Observations of the Eta Aquarid meteor shower in May and the Orionid meteor shower in October (both of which are derived from debris in Halley's orbit) should be started before Comet Halley gets into the inner solar system. Naked-eye counts of meteors will be useful, and more advanced projects such as altitude triangulation, velocity measurements, and spectroscopy will add to the body of knowledge contained in the Halley archives.

In 1985 and 1986, astronomers all over the world will have a supreme opportunity to contribute greatly to our knowledge and understanding of comets in general and Comet Halley in particular. The legacy of observations in the International Halley Watch archives will be used by scientists for decades to come. As a backyard observer, you can contribute important results to that legacy and be a member of a worldwide organization devoted to improving our understanding of the solar system.

Stephen Edberg is an astronomer at the Jet Propulsion Laboratory. He is the coordinator of amateur observations for the International Halley Watch.

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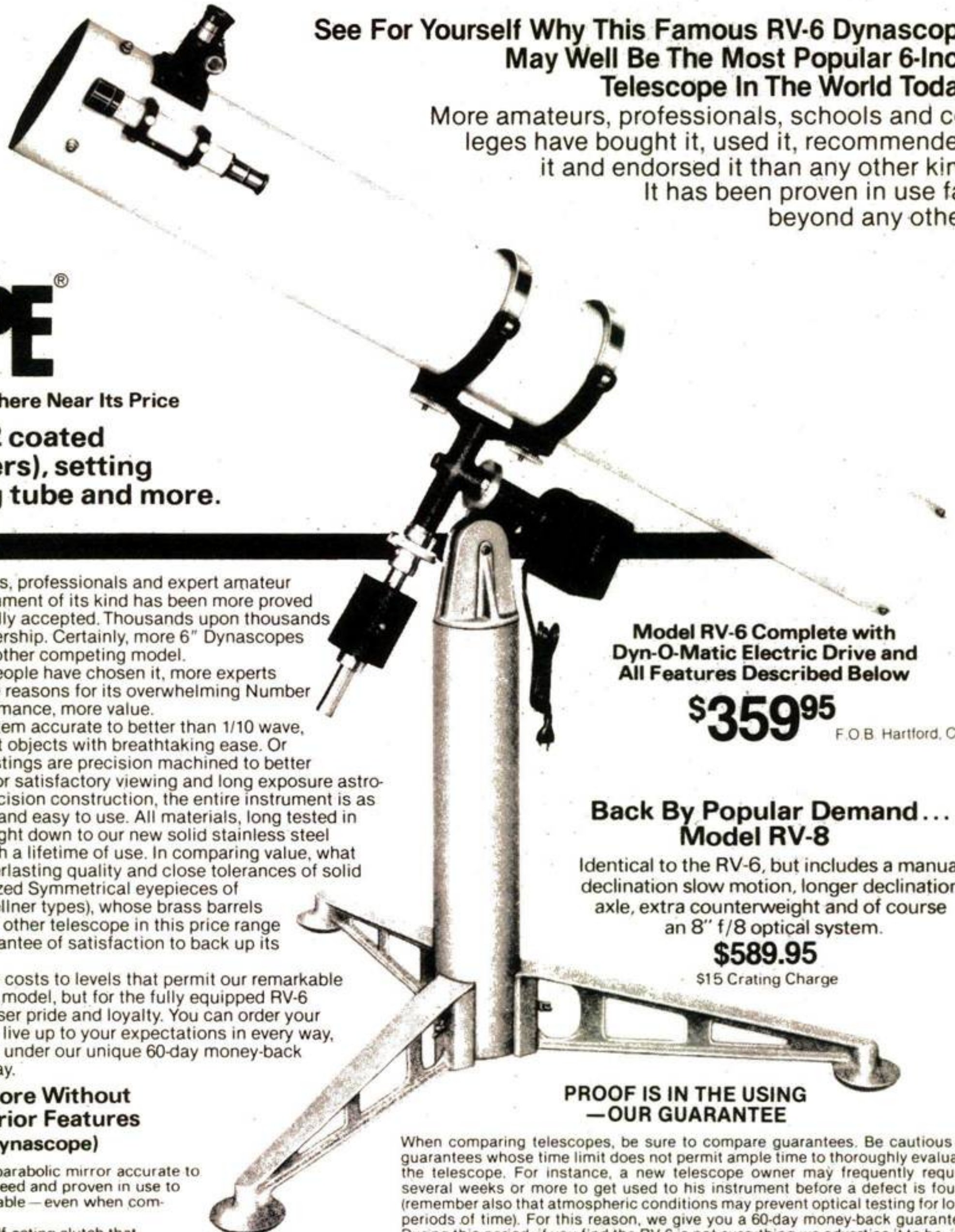

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ASTRONOMY FORUM

Is The Universe A Harsh Mistress?

I must burden you with a personal problem.

Something is really bothering me — but it's not the fact that I had to sell my beloved telescope to pay my sky-high electric bills this past summer. And it's not the frustrating fact that, as of this writing, my idea for a humorous book on amateur astronomy has failed to tickle the fancies of five publishers, either. I realized there would be lean times when I decided to take the plunge into full-time writing; I knew there would come periods when my dedication and perseverance would be tested with spells of transient self-sacrifice, frustration, and failure. I've been an amateur astronomer for more than twenty years; I cut my teeth on trials and tribulations. I'm tough. It takes something pretty darn shocking to bother me.

What's bothering me is tittle-tattle.

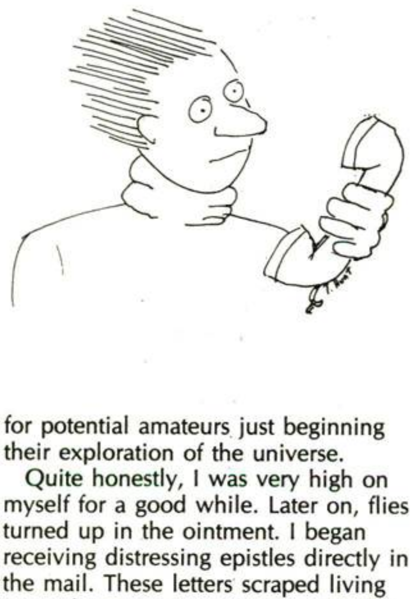
You see, there's this rumor going round that the universe is a very harsh mistress; that she seduces fledgling astronomy enthusiasts into virtual bankruptcy with her beauty, and then proceeds to chew them up and spit them out much the worse for wear.

I know first-hand that this pitiful crumb of idle gossip has already gathered a savage harvest in eleven states, England, and Australia. In each of these sad cases, the rumor proved to be a grim reaper whose scythe severed a person from his or her relationship with the universe, leaving that person bitter, disappointed, confused, and angry.

How do I know this?

Letters, folks. And telephone calls.

Because I am the author of three well-read and -received articles for ASTRONOMY concerning the ups and downs, dos and don'ts of amateur astronomy, I have received and continue to receive letters and phone calls from people all over the world. In some cases, this reader feedback was written to me in care of this magazine and forwarded to me by your kind editor. These — including those letters to the editor concerning my articles and published in ASTRONOMY's letter column — happened to be very complimentary, the stuff of writer's dreams. They made me feel very good because, obviously, my articles had done for the readers what I had intended them to do: help make the way a bit less bumpy and dangerous for potential amateurs just beginning their exploration of the universe.



Quite honestly, I was very high on myself for a good while. Later on, flies turned up in the ointment. I began receiving distressing epistles directly in the mail. These letters scraped living tissue from my astronomer's soul. But the phone calls cut even deeper; they were cries of anger from disenchanted people who were standing out on a ledge, threatening to jump and end it all.

No, there were not cases of threatened suicide. These were individuals calling or writing to say something like this:

"Hey, Mr. Know-It-All, I've really tried to get into this astronomy thing, and I just can't hack it. It's not what I thought it would be. It's not what you promised it would be. I want to get out!" Either that or they wanted to sell me their telescope equipment for cheap — in most cases, dirt cheap.

"What's wrong?" I asked each one of them.

Not one of them could answer that question. Not one could put his or her finger on the source of the anger. But the more I talked with them, the more I realized that all had several unsettling things in common: they'd gotten interested in seriously pursuing amateur astronomy after reading one or more of my articles; they'd invested a great deal of money in the best astronomical hardware available; they'd purchased the most advanced astronomy books and the most expensive star atlases; and now, they felt cheated.

Since I was the spider who had invited them into the parlor, they held me accountable. They blamed me! I don't mind telling you that it was a long, long fall from the high, high mountaintop for this stargazer/writer. When I hit bottom, it hurt. After the fourth call and fifth letter, I figured out what had happened to these people. I was able to pick myself up, dust myself off, and doctor my wounds. I felt better about myself, and a little ashamed for having let myself fall in the first place.

"What had happened?" you ask.

First, not one of them had understood the real message word-woven within the tapestry of my articles. Second, the rumor I mentioned earlier had gravitated to them, and done its dirty work. You must understand that this tittle-tattle ferments the sour grapes of certain people who have tried and failed at

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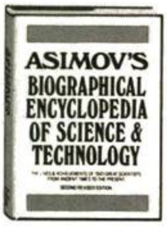

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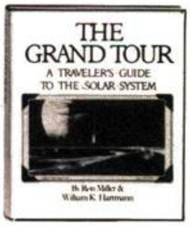

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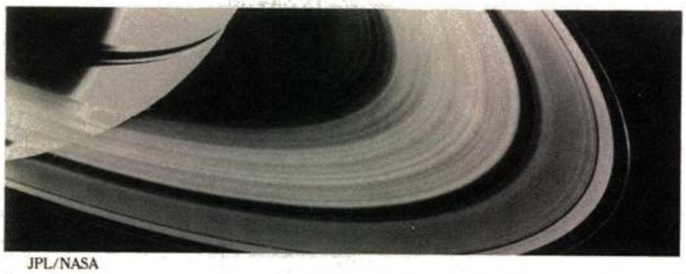

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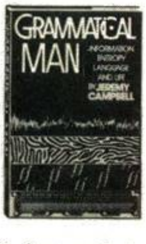

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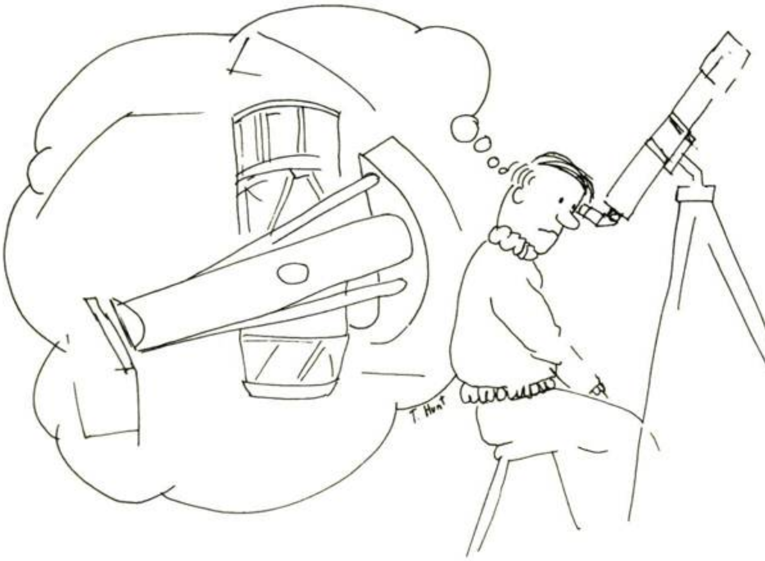
amateur astronomy. The wine of their misery is bitter — and they are always more than willing to share it. If you're weak and unworthy, one sip of it will dissolve any relationship you have with astronomy — but not before you, too, pass the cup. Misery loves company.

I gave these people the benefit of the doubt. I re-read my articles. Yes, each one said exactly what I had wanted it to say. The message was loud and clear. I was satisfied that I had not supplied the potion that had turned these people mad. Certainly they'd drunk the wine of sour grapes — but I had not served them the drink.



What, I wondered, had driven them to drink in the first place?

After a little thinking, the answer to that questions was painfully obvious: in each case, they'd made the mistake of thinking they could buy the favor of the universe with cash instead of love. All of them had OD'd on astronomy hard- and software before paying their dues and getting in shape. They'd started off taking their first "baby steps" weak from a seige of fever picked up from reading the various books, articles (mine included) and ads that glorify amateur astronomy. If you're really into amateur astronomy, you know the fever. It doesn't make you sick at all; on the contrary, it is a very rich, albeit nervous, high. It can impair one's judgement. If one is not careful, one may be not responsible for one's actions.

Some people can deal with the fever. Those who do usually go on to become successful amateur, and sometimes professional, astronomers. Those who fail sometimes come out of the fever screaming, angry, and bitter — easy prey for that vicious rumor.

The really weak ones crash. Over the phone, I heard their crashing.

If you love astronomy as I do, there is no sadder sound.

Wanna talk about feeling helpless? I'm not a psychologist. What could I tell them? What magic words might I have said that would have pierced their drunken stupors and dissolved their disillusionment and bitterness? What lifeline might I have thrown them to save them from the quagmire of self-pity?

They told me horror stories: they said their telescopes were a bunch of junk, would not show lunar craters clearly, or the canals (?!) of Mars, or the spiral arms of galaxies, or the colors of the Orion Nebula. One man, especially, picked on the Orion Nebula, and during the entire long-distance conversation, referred to it as M-31. I didn't have the heart to tell him that M-31 is not the Orion Nebula, but the Andromeda Galaxy.

I knew what I wanted to say, but how do you slap some stranger in the face with the cold fact that it takes a great deal of time, effort, and skill to see and appreciate the subtleties of nebulae and galaxies and planetary detail? These people expect — no, they demand — that each and every object appear in their telescope like it appears on a Palomar photograph.

How does one kindly inform someone that they haven't earned the right to see the heavenly wonders?

One gentleman complained that he had wasted well over two thousand dollars on a 3-inch refractor, observed with it one time, found that he could not discern more than two cloud bands on Jupiter (and no surface detail on any of its moons!). In utter frustration, he wondered if I'd take the pile of junk off his hands for half the price he'd paid for it.

I was sorely tempted. His refractor was one of the best, made by a company with an impeccable, long-standing reputation for delivering the finest state-of-the-art optics. I knew the telescope was not at fault — he'd simple not given the telescope a decent chance. And his mind was made up; the blankety-blank scope was a pile of junk!

What could I say? At the time, three of my close friends were working day and night at two jobs just to save enough to purchase telescopes costing half of what this man's cost. It would have been oh, so easy to take advantage of the situation without saying another word.

Would it have made a difference if I had told him that there have been many nights when I have not been able to make out one cloud band on Jupiter with my 4-inch refractor, when the Moon's craters jiggled in my eyepiece like hula dancers, or that I have never observed any surface detail on Jupiter's moons because that's impossible with an objective of such diameter?

I tried — I really tried — to explain bad seeing, the Dawes Limit, the realistic capabilities of his fine telescope. Metaphorically, I explained that a .22 caliber rifle, no matter how well made or straight-shooting, cannot have the impact of a cannon. Would he listen? No way, bluejay.

One of my friends now has that telescope, and every clear night, he's out exploring the universe, happy as can be, and very grateful to me for finding him such a prize precision eye. It was the least I could do for both parties.

One man's junk is another man's treasure. The individual who considers such an instrument a treasure is worthy, and deserves to have it. The man who considers it junk will never be an amateur astronomer. Now, the man still blames me for using "pretense" to arouse his interest in astronomy, the telescope company for ripping him off, and the universe — if you can imagine it — for not delivering the goods!

Yes, Virginia, some people are unworthy.

And speaking of Virginia, I received this very angry epistle from a woman who lives in that beautiful state. She was mad also, though not at me. She couldn't figure how in the world the company she'd bought her telescope from could have the nerve to label her 12.5-inch reflector as "transportable." She couldn't even lift the tube assembly! And for that reason, she'd never observed with it. Would I be interested in buying the monster cheap? I *thought* of my friends again. I couldn't help it.

Even so, I tried to cool her boiling anger. I informed her that the company

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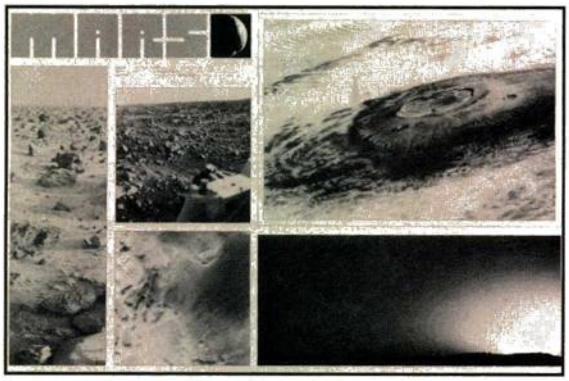

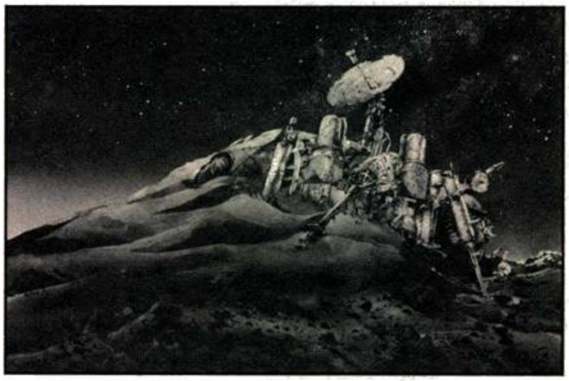

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(I have its catalog) fully describes the weight and dimensions of her telescope. Should I have added that, had she done her homework before ordering, she would have realized that a tube assembly for a 12.5-inch f/6 reflector has to weigh a bit? And that it has to be over six feet long? Should I have gone on to explain that, logically, an equatorial mounting for such a tube assembly would have to be of sufficient mass to support the whole works properly? In such cases "lightweight" means you don't need a crane, but you may have to strain.

Perhaps I shouldn't have, but I did.

Well, she didn't like it one bit. I felt for her, but I didn't feel sorry for her. Increasingly, I find it difficult to feel sorry for anyone who does not use any common sense. Needless to say, I found her telescope a loving home.

Common sense is important, but it's not the whole ball of wax, either. Consider the following caller: He was. angry that it was taking far too long to get his telescope. When he ordered, the company informed him in writing that delivery would be made in approximately four months. When the man called me, the telescope was six months overdue. He was absolutely livid.

What could I say? The same thing has happened to me on three — count 'em, three — occasions, with three different companies. I knew what the man was feeling, but I also knew that there was no magic method known to me, short of marrying the boss's daughter, that would shift their distant assembly line into high gear. You do that sort of thing in the precision business and things really go crazy. I'm married to a lovely woman, so I said, "It's a waiting game." He didn't want to hear that. He wanted me, Mr. Know-It-All, to tell him how to get his telescope within a week.

All I could do was sigh.

If quite a few telescope manufacturers share a major fault, this is it: They fail to cut themselves enough slack when stating delivery times. I'm sure the companies do not do this intentionally, but I do feel they think it is bad business practice to put all their cards face up on the table where this touchy subject is concerned.

Before you judge them for doing such a thing, put yourself in their place. Walk in their moccasins. For a few moments, you be Sales Manager of a fictional firm called Precision-Eye Optics, Inc. Okay?

Okay.

You know it is possible, albeit not probable, that your company can get a telescope fabricated for Mr. Beginning Astronomer in four months. You must believe that because your company has just had printed ten thousand expensive color catalogs stating that in bold print. However, in the last two months there has been a veritable avalanche of orders. Word of mouth has it that Precision-Eye offers one of the best deals in the business, and you know that's true. Also, your ad agency has done one heck of a good job; their campaign has literally given Precision-Eye telescopes sex appeal. To deal with the unexpected surge of orders, your company has been forced to hire new help on the assembly line, and badly needs two more experienced, qualified opticians to boot. Since no qualified opticians have come out of the woodwork, the ones you do have are now working overtime. You know that the new guys on the assembly line need time to get acclimated to this precision business; and sometimes the new help makes mistakes. You have this gut feeling that if there's the slightest hitch, delivery of a new model Precision-Eye will take six months, not four. If any of your suppliers — and there happen to be twenty-three of them — fail to deliver component parts or raw materials, that delivery date could easily stretch to over a year.

GAR·AGE SALE
T Hunt

Now consider: you've got this excited, gung-ho client on the phone who wishes to order a Precision Eye telescope. He's got pen in hand ready to make out a check for payment in full. The first thing he wants to know is: Can you get it to me quickly?

Okay, Mr. Sales Manager. Do you tell him it might take over a year, and risk losing a sale? Or do you tell him that, if all goes well, it could take four months, and hope for the best? Remember now, this job puts food on your table and pays your daughter's dental bills. Be honest. What would you say?

Now, I want you to change your identity: you are now Mr. Impatient Beginner Astronomer. For you, four months is much too long to wait, so you've decided to order from a manufacturer who promises off-the-shelf delivery. But you should be aware that for that luxury either you pay more money, or you take a gamble. Some companies will argue about this, but the special attention in the former case, and the mass production involved in the latter case, dictates it. In the case of expensive state-of-the-art equipment, you pay a premium for the special attention of quick delivery. In the case of a mass-produced telescope, you pay a competitive price, get the telescope quickly, and take a chance, albeit slim, of getting a lemon.

Monetarily, I'm not a rich man. I took a gamble once, and purchased a telescope from a fast-growing company who promised off-the-shelf shipment, guaranteed precision drive, and the finest null-figured optics; in essence, the finest telescope available in its price range. What I received, admittedly in very short order, was a very sick telescope. The drive would not budge because of internal corrosion, and the mirror suffered greatly from a turned-down edge. It was painfully obvious to me that the telescope had not been tested. And yes, it made me angry to pack the thing up and send it back.

Would you like to know whose fault it was? The company had a bum working for them; someone who wasn't doing his job. He was the piece of grit that fouled up the clockworks. The company cheerfully refunded my money, apologized, and fired the bum.

It wasn't a pleasant experience for me or the company. Because I'm human (yes, that's true), I've never been able to order another telescope from them. Many of my astronomical friends own that firm's telescopes, and they are very satisfied. But for me, the bitter aftertaste remains — I was burned and I still have the scars.

But that experience in no way diminished my desire to explore farther into amateur astronomy. Instead, it made me more determined to succeed.

Well, to get back to the angry man who couldn't get his telescope (remember him?), I urged him to be patient. I told him that I had dealt successfully with this company; that they made a great telescope and would not rush at the expense of quality. I assured him that I had never heard anyone complain about the company's product, and that he would be pleased in the long run.

That didn't help at all.

His anger would not be undone.

He canceled his order and purchased a department store import that absolutely could not live up to its claim of "1200X." And you can imagine what that did to his interest in astronomy. Gurgle, gurgle, down the tubes.

Another unworthy bit the dust.

And then, there was the retired man

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Cassegrain Focal Length	1200mm	Circle- R.A.	6-1/2"
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Useful Magnification	30-240x	Accuracy of Circles	
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who claimed he couldn't see a blankety-blank thing through his 16-inch reflector. Well, I've never been able to afford a 16-inch reflector. What could I say to him?

Should I come right out and say, "It's your fault!"?

That's not what they want to hear. They want to be assured that, yes-oh-yes, it is the fault of the manufacturer, and the fault of everyone else who has painted a rosy picture of amateur astronomy and lured them into it all. They're bitter and they're mad and they want someone else to take the rap.

Well, I'm sorry folks, but I won't take it! And I don't think the telescope industry should have to take it, or my precious friends in the world-wide family of amateur astronomers. By golly, I know what's up there in the firmament. And I know what's out there in the form of excellent equipment designed to enable one to appreciate and study the firmament. And in each case, what's there is fantastic! So the only thing I can do is try to nip this anger in the bud — kill the rumor.

Listen up now if you think you'd like to pursue amateur astronomy. And those of you who have made the grade, my precious family and friends, you should listen up, too. You just might be able to nip some buds yourselves. Pruning helps this family tree, for sure.

The universe will not chew you up and spit you out. If you are worthy. If you have a burning desire to surmount all obstacles in your pursuit of amateur astronomy, there is nothing anyone can do or say to stop you. But no one else can light your fire. Either your pilot light is out, or you never had one.

If the word "quit" is part of your vocabulary, then you should forget about this hobby and try something less demanding.

If you don't care enough about amateur astronomy to spend a great deal of basic training doing your "book learnin'," this hobby is not for you.

If you do not have enough common sense to start off gently with a telescope you can handle, seek ye pleasure elsewhere.

If you've never taken the time to learn the fundamentals of optical collimation, and don't intend to, then don't.

But don't blame the instrument.

Or its manufacturer.

Or "poor image quality."

Or the universe.

Don't blame anyone but yourself. And don't, for heaven's sake, begrudge others because they seem to enjoy what they're doing. They've paid their dues. They've approached this hobby, this science, in the proper way. They've toughed out basic training. They've sweated blood to get where they are, and they are now reaping the rewards. Every amateur astronomer is in some way battle-scarred, and they have the medals to prove it.

In amateur astronomy, there are privates, and there are generals. I fancy myself a captain. One of these days, I will be a general, because I'm devoted to the cause 100%.

You say you want to be a general too? You really, really do?

Great! Fine! Wonderful! But are you willing to work slowly, surely up the ranks, or is your heart set on becoming a ninety-day wonder?

Ninety-day wonders have a short survival span in amateur astronomy.

A7 689
T. Hunt

You say you'd like to start out as, maybe, a major? You say you really don't want to mess with being any lower rank because you've got enough money to purchase high-ranking equipment?

Fine. Go ahead. Try it.

Just don't blame me or the universe when everything crashes in on you.

Friend, I don't care how impressive you will look in your major's uniform with all its costume decorations. And the universe doesn't either. It is going to see through all that fluff and chew you up and spit you out. The very fact that you have a weighty 16-inch state-of-the-art reflector and five thousand dollars worth of accessories does not mean a hill of beans to the universe. If she's not obligated to the likes of Carl Sagan, she sure as shootin' is not going to feel obligated to you! You're like a marathon runner who has not yet run a mile — the only thing you're going to get out of the foolish attempt is sore muscles and an aversion to running.

Amateur astronomy is not a race; it is a slow crawl hindered by gravity, bad seeing, and unworthiness. There is no finish line. You must start out crawling uphill. There are no downhill grades until you've crawled a respectable distance. When and if you reach those downhill grades, it is almost a religious experience, a nirvana of sorts. But nobody — nobody — experiences that nirvana until they've, in a sense, built up thick calluses on their knees, steely-strong muscles, and a healthy respect for the course.

Wanna see the calluses on my knees? They're there. And I am proud of them. No, maybe "proud" is not the proper word. Maybe I "appreciate" my calluses because they enable me to continue on, to continue crawling.

You see, you must approach the universe on your knees. She demands humility, respects perseverance, and abhors being taken for granted. She scares the Kool-Aid out of me sometimes — but because I love her so, she gives me a refreshing drink from time to time. Never does she allow me to get up and run, but she continues to let me crawl. But that's all I need.

What sort of individual, you ask, is content with crawling?

Answer: Any amateur astronomer worth his weight in optical glass is content with crawling.

Why?

He knows that crawling is forward progress. After all, he has no cause to rush. The difference between our crawling and our rushing is immeasurable when compared to the vastness of the universe. And too, an amateur astronomer seeks not to be a conqueror, but an understander. He or she is someone special who is willing to take the time and effort required to grow used to something infinite, awe-inspiring, and frightening. Amateur astronomers are painfully aware of their own weaknesses and frailties, and yet they celebrate their place in the scheme of things.

Above all, amateur astronomers are willing to crawl to glory.

I will willingly and joyfully crawl until the day I die. And then, I have the utmost faith that the universe will express her gratitude for my devotion by unfolding her secrets before me.

Unlike the poet Walt Whitman, I do not celebrate myself.

I celebrate what is up there. I celebrate every star, open and globular cluster, planetary and gaseous nebula. I celebrate every planet, cratered wasteland, cradle of life, and gas giant.

I celebrate the most wondrous things.

That vicious rumor is a lie. The universe is not a lady of the evening. She cannot be bought. She is not a harsh mistress.

She must simply be approached with intelligence, common sense, reverence, and humility.

She's a queen, and should be treated as one.

Ken Fulton
Temple, TX

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ASTRONOMY
IN FOCUS

Space Advocates: Hypocrites?

Sir / I must protest Robert Becker's attack on the astronomical community and the space lobby (January In Focus). He appears to be very ignorant of the relationships between money, the space program, and the poor of this country, as well as the world.

Since the depression, this country has spent billions and billions of dollars on the hungry and homeless. While this money has been of great help, it should be obvious by now that money alone will never solve the problem of poverty.

Space advocates do not suggest that expanding the space program will solve the "hideous evils in this country." Rather, space exploration has helped to improve the quality of life here and abroad. One example of this is the ability of drug manufacturers to create new and better drugs in zero gravity — drugs that will help all people, rich *and* poor. The list of similar benefits is very long, and I suggest that Mr. Becker has simply not done his research.

Further, the U.S. and its allies send great quantities of food to poor countries every year, and much of that food rots before it is distributed. Space enthusiasts can hardly be blamed for the mismanagement and corruption in other countries — even though their tax dollars helped to pay for the shipments.

What has Mr. Becker done to help the poor that affords him the right to criticize space advocates? As he apparently maintains that a solution to poverty depends only on the money spent to alleviate it, he has not done much research in this area either.

I greatly resent his opinion that I and others like me are "stinking hypocrites." In fact, I have belonged to several anti-nuclear groups over the past several years, as well as contributed time and money to charities; I am completely against the Reagan administration's arms buildup and reduction of social services — I show my displeasure with my vote, among other means.

Finally, Mr. Becker is completely off track when he says that the "real purpose" of defense is "to bring humankind ever closer to extinction." In fact, it is the responsibility of every country to protect its citizens in the best manner it can — and it is equally the right of every citizen to expect it. Granted, I find the $1.5 trillion spent on arms to be beyond the bounds of that responsibility, particularly in light of the economic and social mess this country now faces.

Critics of space generally evidence the same things again and again: idealistic attitudes, naivete, and ignorance. Do your homework, Mr. Becker. And if you no longer wish to receive the rest of your subscription to ASTRONOMY, perhaps you can arrange to have them sent to nursing homes or public hospitals — I bet you were just going to throw them out.

L.R. Hatcher
Houston, TX

"Self-Indulgent Jerk"

Sir / I am really beginning to get my dander up at being called a "self-indulgent jerk" by the likes of Mr. Becker and those who seek to use the "space exploration" budget issue to attack President Reagan's arms buildup program. Obviously these people don't believe in democracy and freedom or the need to defend it by any means possible.

First of all, many of those injustices Mr. Becker refers to are going to take years, maybe even decades, to resolve, even if we didn't spend a dime on defense. Indeed, a vigorously pursued space-exploration program could contribute significantly toward resolving those injustices.

Americans pour millions — maybe even billions — into booze, cigarettes, junk food, video arcades, sports and other equally useless things. Just think of all the injustices we could solve if we would spend the money presently being wasted on such items.

While I am sickened at the cuts in NASA's budget, I recognize that an adequate defense is absolutely required if we are to remain a democratic and free nation. Didn't Pearl Harbor teach us anything? Even a fool can see that Russian imperialistic adventurism running rampant around the world is a direct result of our failure to maintain a significant military advantage over the Russians.

Make no mistake: the Russians will not stop until they have stamped out freedom and democracy wherever it exists. I believe President Reagan's arms program is an absolute necessity. We must secure freedom and democracy for ourselves, our children, and the world. I would support the total elimination of NASA's budget to achieve this goal.

However, I hardly think it would be necessary. Technical advances resulting from the space program have enabled us to maintain our military advantage in the past, and indeed, could play an essential role in regaining that military advantage.

Steven S. Miller
Grand Terrace, CA

Space: Military Spinoff?

Sir / The comments by John Ascenzi regarding the false issue of "space vs. welfare" (In Focus, December 1982) were right on the mark. ASTRONOMY should be commended for printing his letter when most other pro-space journals seem too timid or constrained by simplistic ideological paradigms to acknowledge his concerns.

Another point that should be mentioned is the alarming tendency of some spokespeople to suggest that weapons systems in space are a blessing in disguise. Their rationale is simple: development of spacefaring capabilities will proceed more rapidly under the aegis of the military because that's where the bucks are. The euphemism heard most often in this context is "spin-off," and the guiding philosophy, almost casually put forward, is "the ends justify the means."

As a long-time organizer, activist, and artist in the pro-space community, I find this attitude abhorrent, unethical, and dangerous. Weapons in space, be they offensive or defensive, are just one more part of the administration's belligerent thrust toward a spiraling arms race that threatens our future both on Earth and in space. If we stay the course, there could very well be a Space Telescope in orbit, but no humans — of any ideology — to use it.

Naturally, many people are aware of the situation, but are uncomfortable with the politics of opposition to a military takeover of space. That's OK. One lesson of the Apollo missions to the Moon is that for more than a decade, much of the tension between the superpowers could be tapped and diverted for the pursuit of more lofty goals — that for more than a decade it was a peaceful pursuit that brought us to a new state-of-the-art in space technology.

Jon Alexandr
Progressive Space Forum
San Francisco, CA

Our New Centerfold

Sir / I appreciate your putting the Star Dome in the center of the November issue. It was long overdue. Will we see the Star Dome on the center pages from now on? I feel that I will use it more if it is, since I can find the center of a magazine in the dark (or even blindfolded).

I doubt that the opinion of one subscriber means very much.

Mel Andrews
Green River, WY

— The Star Dome is in the center because readers like you wrote to us and requested it!

Astro-Bloopers

Sir / For a number of years I have been collecting astronomical inaccuracies in literature, many by well-known writers. Particularly in historical fiction, an author will carefully research living conditions, costumes, speech, and beliefs of a period — but neglect to ask an astronomer about such easily-checked items as the sequence of lunar phases, height of the noontime Sun, stars, or eclipses.

Astronomy, as many authors depict it, is an inconstant thing. I suppose we must forgive poets for stringing words together sonorously, but it galls to read of a lunar eclipse as the crescent Moon was setting. Or, for example: "a pale sun burned overhead that January noon on the Virginia shore," or "a New Moon rose over the palace." Biographies of arctic explorers contain statements like the "low dipping pole star" or "they left all the old familiar stars behind."

Perhaps it's time we compiled an anthology — *Astronomy According to the Authors* perhaps?

Dorothy E. Beetle
Nathan M. Patterson Planetarium
Columbus, GA

Mislabeled Belt

Sir / On page 35 of the December issue, the star Epsilon Orionis is misidentified on the photograph as Eta Orionis. I thought I'd mention this to show you that people really do read your fine magazine very carefully. Keep it coming — there are a lot of us out here who really enjoy ASTRONOMY and look forward to our copy every month.

Joseph Anderer
Tinley Park, IL

Ooops!

The credit for the photo on page 8 of the January issue should have read: Hale Observatories photo courtesy Phillip Angerhofer.

behind the scenes | are you ready?

Figuring out how — despite light pollution, cloudy skies, a busy schedule at work — to become involved in astronomy is a tricky thing. Where are those darned Messier objects anyhow? You search and search and wonder what's wrong. But I still remember, over twenty years later, the sheer pleasure of locating M-31 after several nights of fruitless searching.

The disappointments, and there are plenty of them in store for every astronomer, can lead to discontent, dissatisfaction, even complete loss of your interest in astronomy. Here at ASTRONOMY, we try to be aware of those difficulties and to shape the content of your magazine to make your first forays into observing pleasurable and rewarding, to present honest and, well, "unexaggerated" descriptions of what you can expect from observing the night sky. Yet sometimes we fail. We might present a picture that's a trifle too rosy, that's unrealistically enthusiastic about the "joys of observing." When we do, we hear about it.

I regularly receive letters from irate subscribers claiming, "ASTRONOMY is all telescopes! Cancel my subscription," or "Why won't my telescope see the colors in M-42? You're printing lies!" Well, that's strong stuff, and it certainly doesn't make me happy.

Is ASTRONOMY really "all telescopes"? I hope not! We try to make every issue a mixture of "hard science," "astronomy-as-a-hobby," and paid advertising. We devote roughly 40% of our editorial space to feature science articles, 40% to observing and how-to articles, and 20% to news, opinion, cover and contents. Only one-third of our total pages are paid advertising.

And we try to be honest. I hope we've never claimed that you can see colors in the Orion Nebula, because if we have, I'll tell you right now that we shouldn't have. It's my personal experience that even with a 20-inch telescope under near-perfect skies, only faint and hard-to-see "grey-reds" and "grey-blues" appear in the overall pale grey-green glow of M-42. With smaller telescopes, no color but "pearly white" or "pale grey-green" is visible.

What's this leading to? Simply this: ASTRONOMY is only half the process of communication. You, gentle reader, are the other half. You must hear what we say. Ken Fulton's plea in this month's Forum should be read — and heard — by every potential observer, every desirer of big aperture, every purchaser of precision optics. Ask yourself: Am I ready for the universe?

Sincerely,

Richard Berry

Richard Berry
Editor

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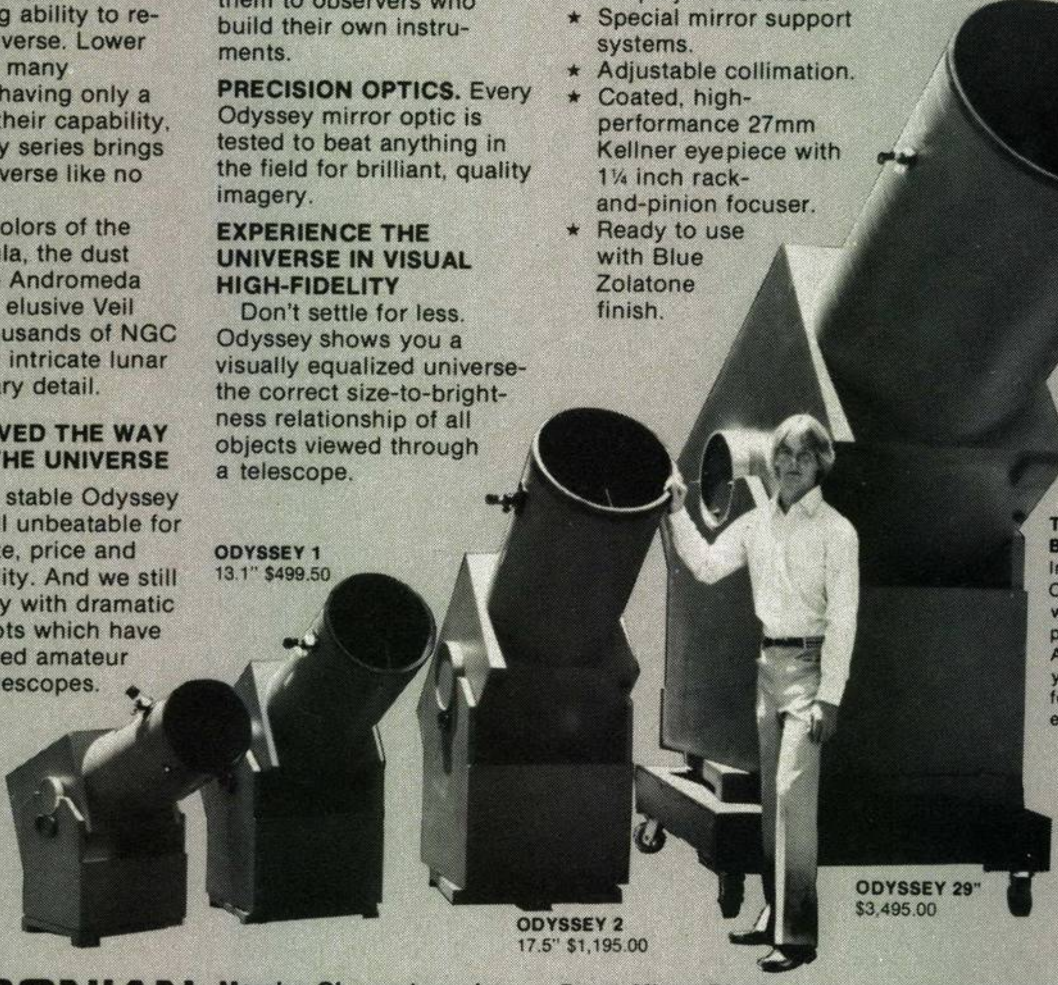

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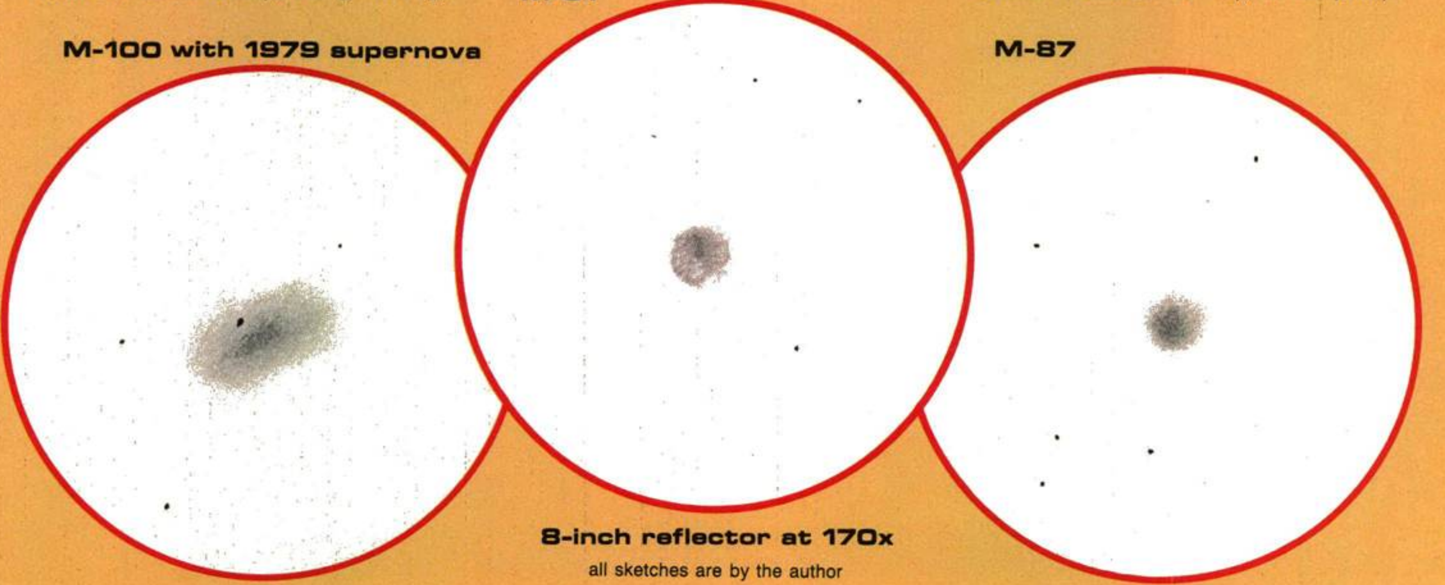
get ready for the virgo cluster

Get ready. Get your star charts, your red flashlight, your observing manuals, and the rusty telescope that's been hibernating for the last two or three months. Warmer weather is coming back, and there are lots of things to explore in the night sky. The dominating feature of the spring sky is a mass congregation of extragalactic debris called the Virgo Cluster, an enormous group of galaxies. No matter how big or small your telescope is, you can go out this spring and scour this dense area, observing all types of galaxies — spiral, barred spiral, elliptical, and even interacting — packed into some 180 square degrees of sky on the border of Virgo and Coma Berenices.

Galaxies, like stars, clump together by gravitation, forming clusters of galaxies. The Milky Way belongs to one such cluster called the "Local Group." It also includes the giant spirals M-33 and M-31 and the irregular Magellanic Clouds (which are close satellites of the Milky Way). But just as stars and star clusters are further aggregated into galaxies, clusters of galaxies are lumped together into what astronomers term *superclusters*. Along with our Local Group, the giant Virgo Cloud is a fellow member of our "Local Supercluster." At a distance of about 42 million light-years — although some astronomers think it could be as far away as 70 million light-years — it lies at the supercluster's center.

So when we look at the Virgo Cloud, we are looking at the densest concentration of galaxies in our vicinity of the universe. At least 100 of the 3,000 members of this cluster are visible in an 8-inch telescope. Fifty cluster members are brighter than magnitude 12.6; our tour will take you to some of them. Remember that the best way to get to know the region is to take a wide-field eyepiece and scan the area. Some of these groups of stars are faint, some are bright, some are detailed, and some are featureless — but by virtue of their existence, they all demand our attention and interest. And on a clear, moonless night this month, a few looks through your eyepiece, which has probably felt neglected in the last few cold weeks, will bear this out.

An appropriate starting place for your tour of the Virgo Cluster is the region around galaxies **M-84** and **M-86**, at the heart of the cloud. Here lie six bright galaxies in just one square degree. M-86 is slightly larger than M-84, although they both glow at magnitude 10.9. The two galaxies are separated by 17′. Both are ellipticals, showing little detail even in moderately large telescopes. They appear as luminous balls of fuzz, simple in the eyepiece but inexplicably complicated in reality. M-86 doesn't seem to want to belong to the cluster: it appears to be moving 286 miles per second *toward* us, while the others display characteristic high redshifts and appear to be quickly receding. **NGC-4388** lies just south of M-86, and is a spindle-shaped spiral radiating at a dim 12th magnitude. Remember that with smaller and dimmer objects, you should use fairly high magnification: about 15x-20x per inch of aperture will give you a reasonably large image scale and will darken the field and increase sky contrast with faint nebulosity. Also in the M-84/M-86 area are **NGC-4435** and **NGC-4438**, both 12th magnitude galaxies. NGC-4435 is an elliptical, and measures a tiny 1′ x 1.6′ across. Needless to say, it is pretty



M-100 with 1979 supernova

M-61

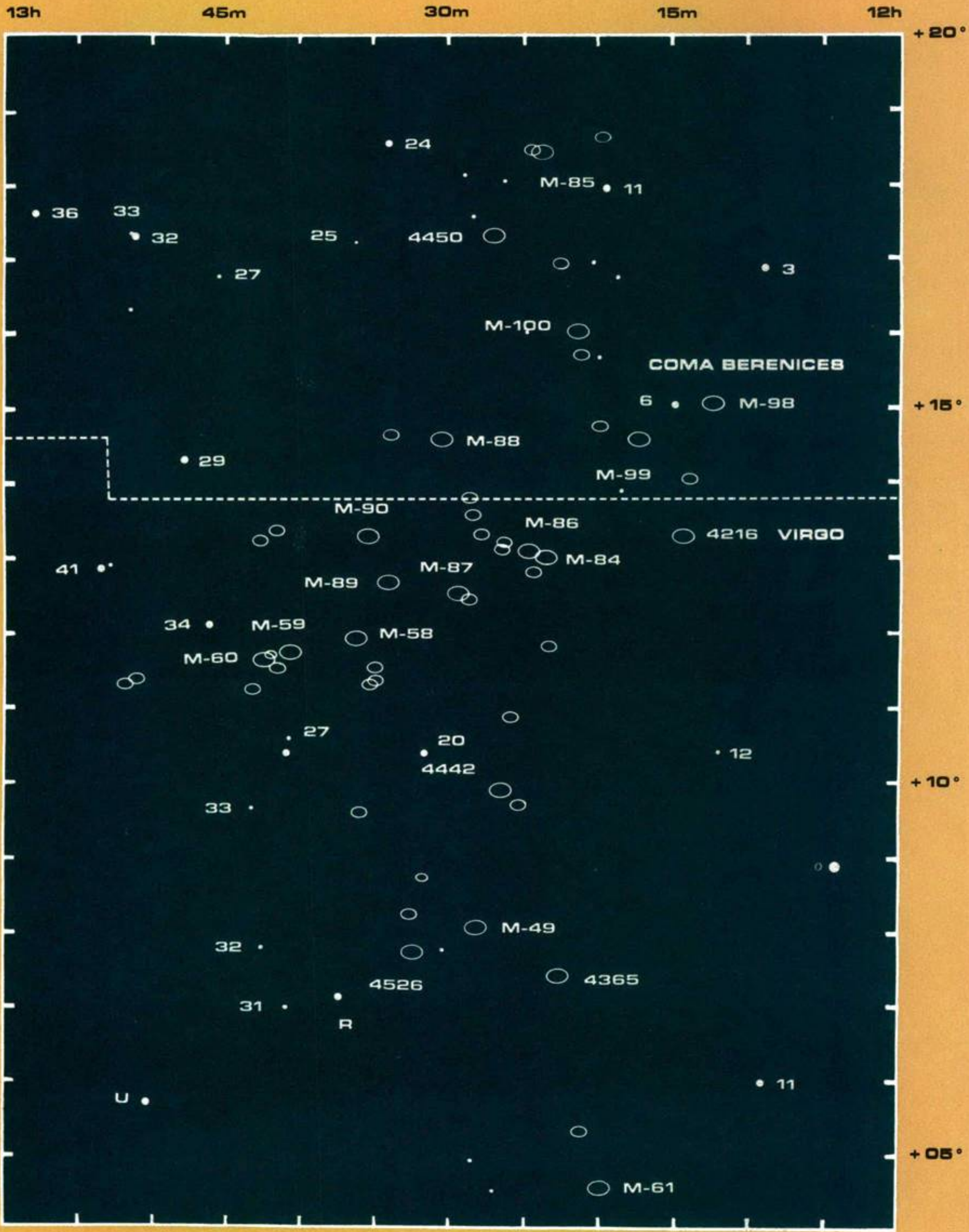
M-87

8-inch reflector at 170x

all sketches are by the author

Jack Newton

Thomas L. Dessert


13h
45m
30m
15m
12h
+20°
+15°
+10°
+05°
24
M-85
11
36
33
32
25
4450
27
3
M-100
COMA BERENICES
6
M-98
M-88
29
M-99
M-90
M-86
4216
VIRGO
41
M-87
M-84
M-89
34
M-59
M-58
M-60
27
20
4442
12
33
M-49
32
4526
4365
31
R
11
U
M-61

Bill Iburg

Lee Coombs

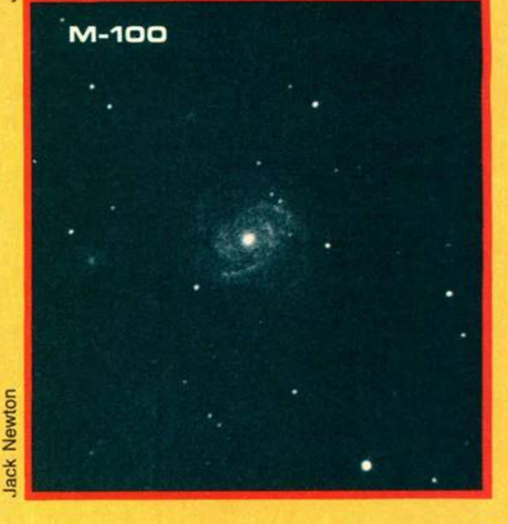
The 50 Brightest Galaxies in the Virgo Cluster

Object		R.A. (2000) Dec.		Mag.	Size	Type
4192	M-98	12h 12m	+15°03′	11.4	8.1′x2.5′	Sb
4212		12h 14m	+15°03′	12.1	2.6′x1.6′	Sc
4216		12h 14m	+13°17′	11.3	7.6′x1.6′	Sb
4254	M-99	12h 17m	+14°34′	10.5	5.2′x4.8′	Sc
4293		12h 20m	+18°32′	11.7	4.6′x1.8′	Sa
4298		12h 20m	+14°45′	12.5	3.0′x1.6′	Sc
4303	M-61	12h 20m	+04°37′	10.4	5.5′x5.0′	SBc
4312		12h 21m	+15°41′	12.5	3.4′x0.9′	S0
4321	M-100	12h 21m	+15°58′	10.8	6.3′x6.0′	Sc
4324		12h 22m	+05°23′	12.5	1.9′x0.9′	Sb
4350		12h 22m	+16°50′	12.0	2.3′x0.7′	S
4365		12h 23m	+07°28′	11.0	3.6′x2.5′	E
4371		12h 23m	+11°51′	12.1	2.4′x1.6	SBa
4374	M-84	12h 24m	+13°02′	10.9	2.6′x2.1′	E
4382	M-85	12h 24m	+18°20′	10.5	4.6′x3.2′	E
4388		12h 24m	+12°48′	12.2	4.6′x1.0′	S
4394		12h 24m	+18°21′	12.2	3.5′x3.0′	SBb
4406	M-86	12h 25m	+13°05′	10.9	3.4′x2.4′	E
4417		12h 25m	+09°44′	12.3	2.6′x0.8′	E
4419		12h 25m	+15°11′	12.2	2.8′x0.9′	Sc
4429		12h 26m	+11°15′	11.7	3.7′x1.5′	Sa
4435		12h 26m	+13°13′	11.8	1.6′x1.0′	E
4438		12h 26m	+13°09′	11.9	7.1′x2.8′	Sb
4442		12h 27m	+09°57′	11.4	3.2′x1.2′	SBa
4450		12h 27m	+17°13′	11.4	3.7′x2.6′	Sb
4459		12h 28m	+14°17′	11.9	1.7′x0.7′	E
4461		12h 28m	+13°20′	12.4	2.9′x1.1′	S
4472	M-49	12h 28m	+08°08′	10.1	4.8′x3.9′	E
4473		12h 28m	+13°34′	11.7	2.4′x1.3′	E
4477		12h 29m	+13°47′	11.8	3.0′x2.5′	SBa
4478		12h 29m	+12°28′	12.5	1.2′x1.1′	E
4486	M-87	12h 29m	+12°32′	10.7	3.8′x3.5′	E0pec
4501	M-88	12h 31m	+14°34′	10.9	6.0′x3.3′	Sc
4526		12h 33m	+07°50′	10.7	5.4′x1.5′	Sa
4535		12h 33m	+08°20′	11.1	6.5′x4.5′	SB
4548		12h 34m	+14°38′	11.9	4.8′x3.9′	SBb
4552	M-89	12h 34m	+12°42′	11.3	2.0′x2.0′	E
4564		12h 35m	+11°35′	12.1	2.0′x0.7′	E
4567		12h 35m	+11°24′	12.3	2.5′x1.6′	S
4568		12h 35m	+11°23′	12.2	4.1′x1.7′	S
4569	M-90	12h 35m	+13°18′	11.2	7.1′x3.3′	Sc
4578		12h 36m	+09°37′	12.5	2.6′x1.9′	E
4579	M-58	12h 36m	+11°57′	11.0	4.5′x3.7′	SBc
4621	M-59	12h 41m	+11°47′	11.4	2.6′x1.6′	E
4638		12h 41m	+11°35′	12.2	1.4′x0.6′	E
4639		12h 41m	+13°23′	12.3	2.0′x1.4′	Sc
4647		12h 42m	+11°43′	12.0	2.5′x2.1′	Sc
4649	M-60	12h 42m	+11°41′	10.6	3.4′x2.8′	E
4654		12h 42m	+13°15′	11.7	4.1′x2.3′	Sb
4660		12h 43m	+11°18′	12.3	1.6′x0.8′	E
4754		12h 51m	+11°27′	12.0	3.2′x1.6′	SBa
4762		12h 51m	+11°23′	11.8	5.6′x0.8′	Sa

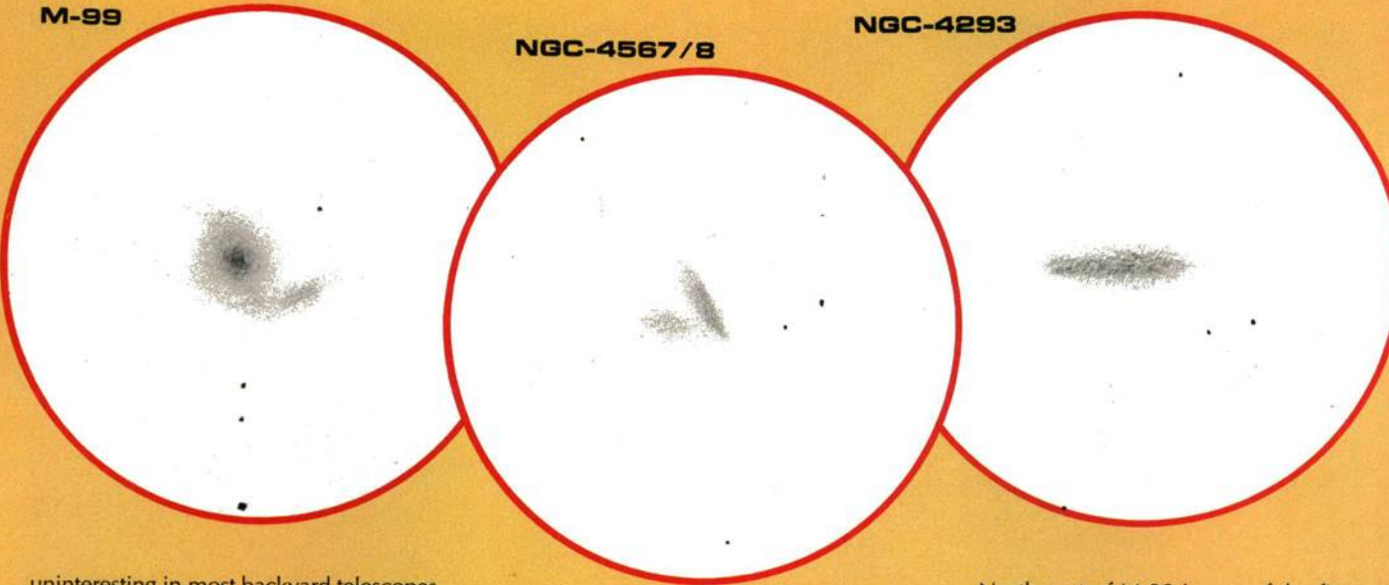
Thomas L. Dessert

NGC-4567 & NGC-4568

Jack Newton



Jack Newton



uninteresting in most backyard telescopes. NGC-4438, on the other hand, is an Sb type spiral that spans 7′. It is a fascinating object under good dark skies.

The giant elliptical galaxy **M-87** lies to the southeast of the central core, and is one of the most remarkable objects known in the universe. It contains about 790 billion solar masses and some 1000 globular clusters, and is moving away from us at a rate of 755 miles per second. Compared with the Milky Way, which weighs in at about 100 billion solar masses and holds sway over 100 globular clusters, these statistics are impressive. Less impressive, however, is the view of M-87 through a small telescope. Even though it is fairly bright — magnitude 10.7 — it is featureless, as are virtually all ellipticals.

Another elliptical lies about 5° south of M-87, and shines at magnitude 10.1 — it is designated **M-49**. M-49 appears much the same as M-87, shining at magnitude 10.1 and measuring about 5′ x 4′ across.

Some 3° south of M-49 is **M-61**, a 10th magnitude face-on spiral that is telescopically very interesting. It is fairly large in the eyepiece — a roughly circular 5′ — and with large telescopes of at least 10-inch aperture it presents delicate, knotty spiral arms. Try using medium powers on this galaxy when the seeing is good — you'll be surprised at the view.

Moving back up to the center of the group, **M-59** is about 3° southeast of the heart of the cluster. It is small — measuring 2.6′ x 1.6′ — but is fairly bright at magnitude 11.4. Observers who use large reflectors may see some hint of detail in M-59, but it doesn't reveal much since it is elliptical in form. Another elliptical in the area is **M-60**, which is slightly brighter, shining at magnitude 10.6. Although it is a bit larger — 3.4′ x 2.8′ across — it, too, is pretty featureless. M-59 and M-60 are very dense galaxies: M-60, for example, holds a trillion stars — five times as many as the Milky Way — in its 25,000 light-year diameter. M-60 has a nearby companion galaxy, which may have undergone an interaction with the big elliptical. **NGC-4647** is a 12th magnitude Sc-type spiral with only one-tenth of the mass of M-60, but it could have passed close by it.

Two huge spirals and another elliptical reside on the eastern side of the central portion of the cluster, all of which were recorded by Messier in his catalog. **M-89** is a small, run-of-the-mill elliptical, not exciting as galaxies go. It spans only 2′, and glows dimly at magnitude 11.3. To observe these ellipticals as best you can, about all you can do is to wait for an excellent night of seeing and use a large telescope with fairly high powers. **M-90** also shines at 11th magnitude, but is much more interesting. It's an Sc-type spiral, measures a full 7′ across, and displays a bit of detail — probably visible as mottling — in medium-sized telescopes. M-90 encases 80 billion solar masses, and is about 80 thousand light-years in diameter. Equally interesting is **M-58**, a barred spiral of SBc-type, which also shines at 11th magnitude. It's rounder than M-90, measuring 4.5′ x 3.7′, and probably shows a slight amount of detail in large backyard scopes.

A curious pair of galaxies lies just south of M-58, and is a fascinating sight under good seeing conditions. Astronomers nicknamed the galaxies **NGC-4567** and **NGC-4568** the "Siamese Twins" because they are actually two interacting spirals. Both are a little fainter than 12th magnitude, so you'll have to employ at least a 10-inch scope to see them as anything more than a fuzzy patch. Large backyard instruments can probably separate the two images and discern a view of galaxy interaction.

In the northern reaches of the Virgo cluster are more bright galaxies, such as **M-88**, a fine Sc-type spiral that is just brighter than 11th magnitude. It's a large galaxy — over 5′ long — and with high magnification is a pleasing sight in telescopes over 10 inches in aperture.

Northwest of M-88 is one of the finest galaxies in the entire cluster, Sc-type spiral **M-100**. This galaxy is roughly comparable to the Andromeda Galaxy, but is 20 times farther out in space. So take your telescope out on an excellent night, find M-100, and use a relatively high magnification. Even though we don't see M-31 and M-100 at the same inclination, it's a good way to see the effects of distance on similar objects. M-100 produced a brilliant supernova in 1979, which rose to slightly brighter than magnitude 12 for a short time. This celestial visitor has faded now, but the galaxy still provides a fine view.

M-99 is another beautiful Sc-type spiral, and is very bright at magnitude 10.5. M-99 is pretty large, and we view it nearly face-on, so on nights of good seeing — with a telescope of 12-inch aperture — you can observe spiral arms in this galaxy. This collection of stellar material is about 50,000 light-years across, and contains 50 billion suns. Some of the galaxy's activity is evident in large reflectors as groups of knotty bright patches intertwined with the galaxy's arms. M-99 has one of the highest redshifts of any Virgo cluster members.

Another nearby spiral is **M-98**, slightly larger and more elongated than M-99, and about the same brightness. M-98 is an Sb system, seen nearly edge-on with respect to our line of sight. It doesn't display a lot of detail, therefore, but shows a stellar nucleus and is quite attractive as a silvery needle-shaped light source.

There are many forms of galaxies in the giant Virgo cluster. None of the very brightest or largest of the galaxies is in this region, but rather a huge number of varied fuzzy patches, some of which show magnificient detail under the right conditions. The time is once again here; galaxy hunters the world over are getting ready for our best view of a cloud of these vast cosmic structures of gas and dust. They're getting out their binoculars, telescopes, red flashlights, star charts, and sketchpads. Are *you* ready for the Virgo cluster?

—David J. Eicher

ASTRONOMY
REVIEWS

The Lighter Side of Gravity
Jayant V. Narlikar
194 pages, hardbound, $17.95;
paper, $8.95
W.H. Freeman (1982)

Of the four basic forces in nature (gravity, electromagnetic force, the strong and the weak nuclear forces), gravity is the one we are most familiar with. We encounter this relentless force every moment of our lives, yet we deal with it on an unconscious level. Were it to cease its invisible pull, the most profound and bizarre conditions would result, altering our environment in a cataclysm unmatched in the history of the Earth. And if we let our imagination roam beyond the Earth, out past the solar system and into the farthest reaches of space, we still find gravity there, working its magic.

For those whose interest and curiosity include the exotic effects of gravity in space and time, Narlikar's *The Lighter Side of Gravity* will be an enjoyable book. The volume offers the general reader an easily-grasped overview of the properties of gravity and how it may affect space, time, and matter. Written by an astrophysicist who has authored other related books, it's appropriate that most of this book focuses on the extraterrestrial effects of gravity. The approach and examples are adequate for a good, fundamental understanding of this force which permeates every nook and cranny of the universe — and general readers will be relieved to know that little mathematics has been used!

Crammed with charts and drawings (some lifted directly from an earlier textbook co-authored by Narlikar and Fred Hoyle), *Lighter Side* commences with a brief historical overview of gravity as it was understood by Aristotle and Galileo. It next describes motion and movement according to Newtonian physics, especially as applied to the solar system. Narlikar builds a picture of gravity by describing its readily-observable, theoretical characteristics. Topics covered include: terrestrial tides, planetary motion, stellar fusion reactions, and the presumed structure of the universe. All these are introduced on an elementary level, but with sufficient clarity to ensure understanding with only one reading.

Until comparatively recently, gravity was believed to behave exactly as Newton predicted, regardless of when and where its effects were observed. Today, however, it is known to deviate from this in ways that involve non-Euclidean geometry and Einstein's ideas of space-time. Narlikar touches upon the basic incongruities existing between Newtonian and Einsteinian conditions under which they arise.

In a chapter titled "Ocean Tides and Binary Stars," the forces and dynamics present in a close binary star system are described. Theoretically, as gravity acts upon the two stars of the system, a one-way exchange of stellar material takes place. Such an occurrence, explains Narlikar, produces gravitional radiation, a phenomenon not unlike electromagnetic radiation.

The logical "final step" of gravity is the black hole. The author presents adequate information leading to simple understanding of this concept, so widely invoked by astrophysicists. He describes the major characteristics of a black hole, including the event horizon, the curving of space-time, the colossal tidal forces involved — all of which lead him to that inevitable conclusion, the singularity, a region of space-time where the known laws of physics cease to operate.

The author mentions Einstein's failure to formulate a unified field theory in which the four natural forces are connected. Work in ths area by physicists is continuing, and if such a grand scheme is eventually discovered, our understanding of gravity will be immeasurably enhanced.

All in all, there is ample fodder for the imagination in this book, as well as much solid theory and fact. The book concludes with some provocative questions for the reader to ponder. Do supermassive black holes exist? Are they to be found at the center of globular star clusters? Or perhaps hidden at the center of some galaxies? Or maybe in quasars?

With exquisite understatement, Narlikar writes, "At present there are still some matters to be settled." *Gail O. Clark.*

JPL and the American Space Program
Clayton R. Koppes
299 pages, hardcover, $19.95
Yale University Press (1982)

Institutional histories tend to be deadly dull: the general reader who cares to wade through the minutiae of who said what to whom in a memo on such-and-such a date is a rare person indeed (John Logsdon's *The Decision To Go To the Moon* was a prime offender in this regard). And yet, for all their concentration on day-to-day details, these books *can* be exciting, provided they chronicle places where great events were happening — and the Jet Propulsion Laboratory certainly qualifies as that.

Koppes begins his story with JPL's forebearer, the Guggenheim Aeronautical Laboratory of the California Institute of Technology (GALCIT). GALCIT was founded in 1936; its staff performed a lot of research in rocketry, including the development of the solid-fueled JATO rockets used by the armed forces in WW II. To reflect its changing role, GALCIT's name was switched in 1944 to the Jet Propulsion Laboratory. Throughout the latter '40s and early '50s, JPL developed tactical and intermediate range missiles for the Department of Defense. In so doing, it established a technical competence in designing both solid- and liquid-fueled rockets that allowed it to jump right in when NASA and the rest of our space program got underway in the late '50s.

But JPL had more to offer than just technical competence; it prided itself on being the "big dream shop." JPL staff worked hard to come up with the wildest ideas, the most far-out concepts — and then worked like crazy to get them flown.

The roll-call of projects is certainly impressive: Mariner, Surveyor, Viking, Voyager — all have been outstandingly successful. Galileo, the next in the line, promises to do as well.

But not everything went without a hitch: JPL's most spectacular failure was in the Ranger program of the early to mid-1960s. Intended as a preliminary photographic survey to see if the lunar surface could support the weight of a manned lander, Ranger was to fly on an impact course to a given area of the Moon's nearside. A few minutes before impact, television cameras were to be turned on and a sequence of photos would follow until the craft smashed into the surface. With its last photo coming only a few dozen feet before impact, Ranger was to provide the first good close-up look at the Moon's surface materials.

JPL's problem was that Rangers 1 through 5 had all failed for one reason or another. These high-visibility botches prompted long bouts of institutional soul-searching: the original project manager was fired, engineering designs were re-thought, all scientific experiments (except the TV) were removed, disputes with sub-contractors were hashed out — even JPL's status as a quasi-academic laboratory was called into question. Finally, after the most thorough testing any spacecraft had yet gone through, Ranger 6 was declared ready for launch. It roared aloft on an Atlas-Agena rocket and after a "textbook perfect" flight, it failed too.

In the aftermath of the investigations (which this time involved Congress as well), the last of Ranger's faults were found and corrected, and Rangers 7, 8, and 9 all performed up to specs. But however painful the process must have been for those involved — and Koppes shows clearly that it was extremely so — the result was beneficial. JPL came out of the 1960s a highly-skilled organization that could design sophisticated spacecraft and make them work well. Koppes makes a good case that something like the cathartic Ranger experience was necessary if more advanced projects such as Viking and Voyager were to happen.

Although he is writing about an institution, the author never loses sight of the fact that institutions are chiefly aggregations of people. Working from interviews with many of the participants, Koppes displays a fine appreciation for personality and how it can affect the way people interact. To pick just one example, William H. Pickering (director of JPL from 1954 to 1976) had a managerial style that drove several NASA administrators almost crazy with frustration. Pickering believed that the lab's successes came from fostering a loosely-structured "university atmosphere" among its staff, and accordingly he gave them pretty free rein. NASA as a whole, and administrator James Webb in particular, believed in corporate-style management: set goals to a timetable, force people to adhere, and keep a close eye on the money. In all fairness, NASA's role as watchdog over public funds *was* important, but the three-cornered squabbles between NASA, JPL, and JPL's parent, Caltech — detailed by Koppes with quotes from letters and memoranda — were colossally counterproductive for space science, and would have been largely avoided had both sides shown a little more tolerance for the others' methods. Let's hope the lesson has been learned.

Dedicated space buffs will find *JPL and the American Space Program* "must" reading, despite its deliberate avoidance of the scientific imperatives that drove the projects themselves. The reader whose interest in the space program is more general might consider skimming through a library copy or even skipping the book altogether. But bear in mind that this is much more than a dusty tome of institutional history: although Koppes doesn't focus on what the general public might call the heart of the space program, he does explain clearly the forces that worked to produce some of the greatest space triumphs mankind has yet accomplished. *Robert Burnham.*

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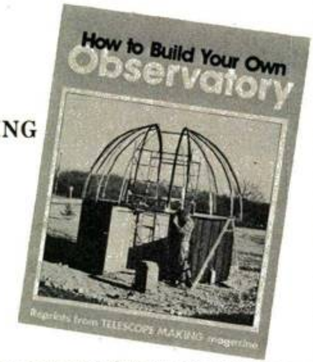

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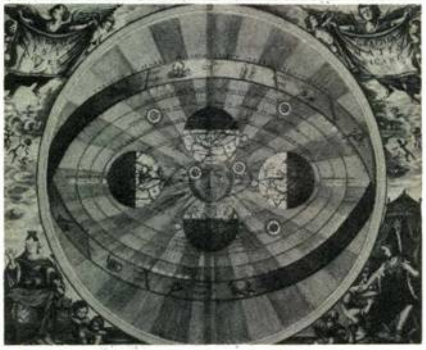

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Supernovae: A Survey of Current Research

M.J. Rees and R.J. Stoneham, eds.
590 pages, hardcover, $69
D. Reidel (1982)

Why do massive stars explode? Theorists are just beginning to understand the physical mechanisms involved in supernova explosions, and this volume presents papers that review the present state of the subject. Stellar evolution, supernova statistics, and pulsars are discussed, as well as recent radio, ultraviolet, and X-ray observations of supernova remnants. The book is based on a NATO Advanced Studies Institute held at Cambridge, England, in 1981.

Extragalactic Astronomy

Lecture Notes from Cordoba
J.L. Sersic
245 pages, hardcover, $49.50
D. Reidel (1982)

Sersic has condensed material from nearly two decades of lectures at Argentina's Cordoba University. Aimed at a professional audience, the monograph discusses galactic morphology and classification, active galaxies, the extragalactic distance scale, and cosmology.

The Rebirth of Cosmology

Jacques Merleau-Ponty and
Bruno Morando
Translated by Helen Weaver
284 pages, paperback, $9.95
Ohio University Press (1982)

This is an unusual book. In three sections, a philosopher and an astronomer describe ancient, classical, and modern cosmological thought. That in itself is not so unusual, but the construction of the book is very different from otherwise similar works. Each topic is discussed in two essays — one from a philosophical viewpoint, the other exploring the science of the period. Their history illustrates how cosmology has oscillated between the realms of philosophy and science through the ages.

Quantum Fields in Curved Space

N.D. Birrell and P.C.W. Davies
340 pages, hardcover, $49.50
Cambridge University Press (1982)

As the title implies, this is a book for professionals only. From the evaporation of black holes to the creation of particles in the early universe, the book is a comprehensive review of gravitational effects in quantum field theory. This work is the first attempt to collect and unify the vast literature on the subject, which has developed rapidly over the last decade.

The R.A.E. Table of Earth Satellites, 1957-1980

D.G. King-Hele, J. A. Pilkington, H. Hiller, and D.M.C. Walker
656 pages, hardcover, $75
Facts on File (1982)

Well, it *is* expensive — but where else will you find a complete compilation of facts on every satellite ever launched? The *Table* lists the names and dates of launches, orbital lifetimes, mass, dimensions, and at least one set of orbital parameters for the 2145 satellites launched from October 4, 1957 to December 31, 1980. It also tells you about the fragments (protective shrouds, upper stages, broken pieces, etc.) that have also wound up in orbit — in all, over 12,000 objects are tabulated. (By the way, R.A.E. stands for the Royal Aircraft Establishment of Farnborough, England, whose staff has done a superb job in this book — even if it is one with a limited appeal.)

Lightning, Auroras, Nocturnal Lights

William R. Corliss
242 pages, hardcover, $11.95
The Sourcebook Project (1982)
[publisher's address: P.O. Box 107, Glen Arm, MD 21057]

This is a compilation of geophysical anomalies, or unusual events, that has been culled from the scientific press. Most of the entries date from the last century.

By Jupiter: Odysseys to a Giant

Eric Burgess
155 pages, hardcover, $24.95
Columbia University Press (1982)

Four spacecraft have visited Jupiter, all of them on flyby missions: Pioneers 10 and 11, and Voyagers 1 and 2. In the 5½ years between the encounter of Pioneer 10 and that of Voyager 2, our store of data about Jupiter increased dramatically — and over the years since has spawned a similar advance in our knowledge of the planet. Eric Burgess is a well-known science writer who has published several books on the space program; *By Jupiter* tells the story of both the missions and their scientific results for the general reader.

The Cosmic Serpent

Victor Clube and Bill Napier
299 pages, hardcover, $17.95
Universe Books (1982)

In the past decade, the evidence has been mounting steadily that the Earth gets hit by extraterrestrial material in the form of comets, asteroids, and meteorites on what — geologically speaking — is a pretty regular basis. In *The Cosmic Serpent*, two astronomers at Edinburgh's Royal Observatory undertake a review of the evidence for catastrophic impacts and discuss the implications for present-day life on Earth.

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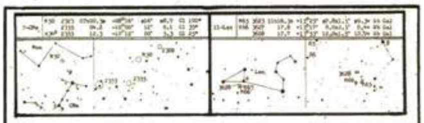

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eye on the sky

spring skies bring bright planets

by Fred Schaaf

the wanderers

Spring begins as the Sun reaches the vernal equinox at 11:39 p.m. EST (coincidentally, the same minute winter began last December) on March 20th. Once again, this season will be the best for viewing the planets: within the next few months, all but one will reach their brightest for 1983. Major oppositions, greatest elongations, and conjunctions do not occur during March, but all month long there are bright planets to see.

The first planet visible after sunset is brilliant **Venus**. Although still far from greatest elongation, the 30° elongation of Venus from the Sun places it rather high in the evening sky at this time of vernal equinox. At such a great elongation, the −3.4 magnitude planet is the brightest "star" in the evening sky.

During March, Venus tracks across Pisces and Aries; although it appears to be headed toward the Pleiades, the planet will actually pass well south of them in April. Not until 1988 will Venus repeat the fine April conjunction with the Pleiades that occurred in 1980. (The 1988 event will be an even closer meeting.)

If you search carefully along the ecliptic and well to the lower right of Venus as darkness falls, you may barely glimpse a very dim point of light.This is **Mars**, now at an elongation of 18° from the Sun and only magnitude 1.5 on the first day of spring. What is the last day you can see it with your naked eye?

After Venus leaves the dark sky, turn your attention to the southeast. At about the same declination as Spica, although trailing well behind it, is the golden light of **Saturn**. During March, Saturn is moving backward just to the south of somewhat ruddy, magnitude 4.2 Kappa (κ) Virginis. With binoculars you can see that Saturn is even closer to several much fainter stars. The ringed planet is now about 0.5 magnitude, roughly midway in brightness between Arcturus and Spica. It continues to retrograde and brighten as it heads toward a late April opposition.

Later in the evening, **Jupiter** is an impressive object as it climbs from the horizon above Scorpius. The giant planet moves among the stellar background at its slowest these nights (it is on the eastern end of its retrograde loop), so it stays within a few degrees of the star Omega (ω) Ophiuchi and fifth-magnitude **Uranus**. Jupiter will glow at -1.8 beginning at quadrature — that is, 90° from the Sun. The planet will be at opposition around Memorial Day, distinctly brighter and visible all night long. If you stay up very late on a March night you can see that Jupiter is now near the broad, bright stream of the summer Milky Way for the first time in nearly a decade.

As the outer planets all approach opposition, the eastern sky is bare of planets in the pre-dawn hours, with one exception. **Mercury** hangs low in the southeast at the beginning of the month and becomes increasingly difficult to find. It is unfortunate that Mercury is so unfavorably placed when it passes just 3 minutes of arc south of 4.4 magnitude Iota (ι) Aquarii on the morning of the 6th. Mercury is farthest from Earth on the 20th and reaches superior conjunction on the 26th. The only good news about Mercury is that it will put on its best evening display of the year — next month.

the starry sky

In the past few months, the clusters of Taurus have fascinated us. Now the Pleiades and even the Hyades are approaching the bounds of evening twilight — try looking for the Seven Sisters as they first appear in the afterglow. Brilliant Orion and Canis Major, with its great star Sirius, still hold sway in the southwest as major attractions. But in March these constellations are being supplanted by newcomers high in the spring sky.

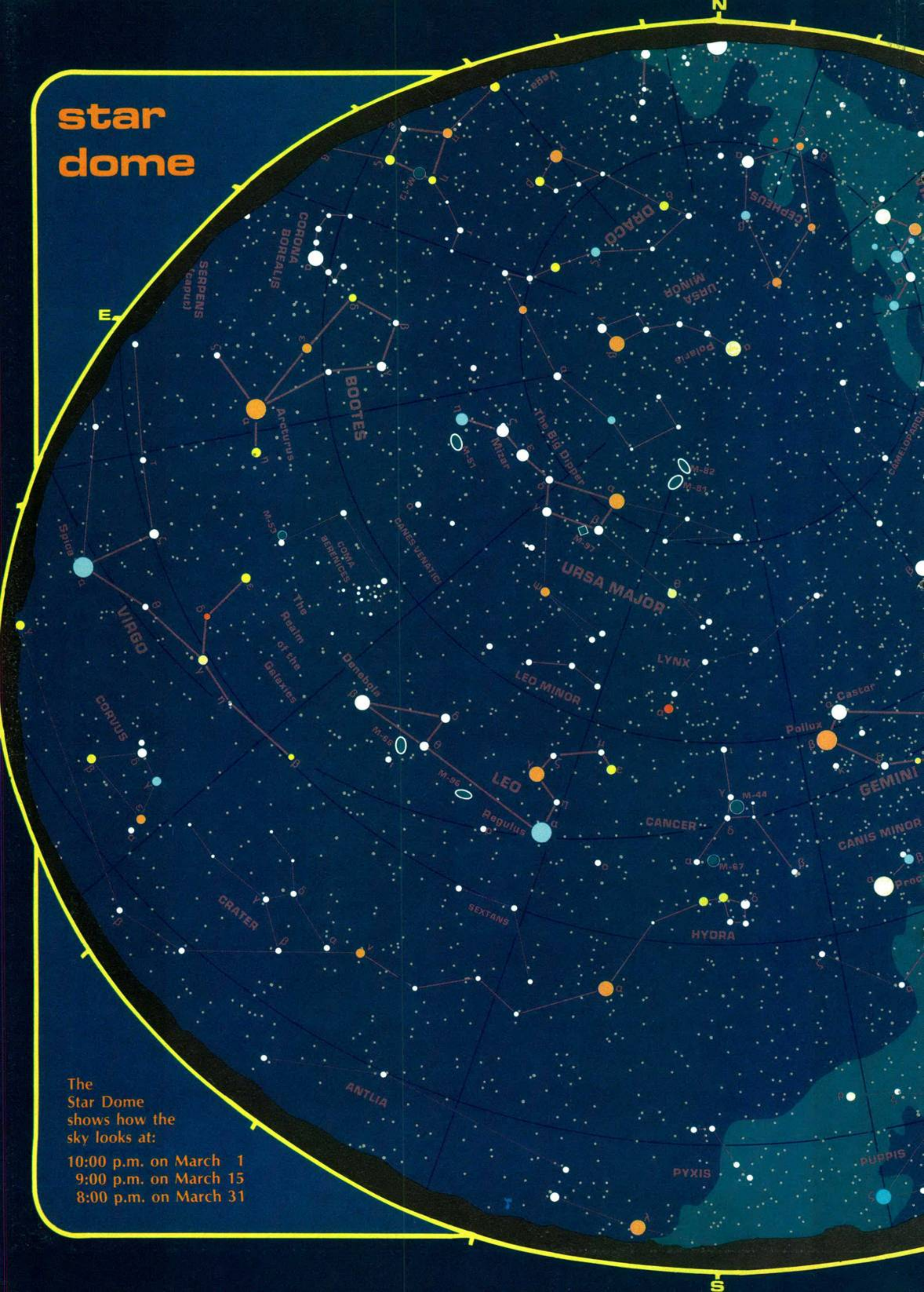
One of these constellations lies so far north that it is seen in autumn before Taurus, yet is still partly visible far into May for most of us — **Auriga** the Charioteer. There is still plenty of time to observe it as spring arrives, especially its brightest luminary, **Capella**. No first-magnitude star lies as far north as this object. Located at +46° declination, Capella is technically a circumpolar star anywhere north of 44° north latitude. Observers in Glasgow and Edinburgh in Scotland can see Capella at least 10° above their northern horizon all year long.

A more southerly but almost as brilliant star for March is **Procyon**. Many sources call it white, but I detect a slight yellowish tinge — though not as strong as that of Capella. Procyon is in the Lesser Dog, **Canis Minor**. Strangely, Procyon has a white dwarf companion even smaller than that of the other Dog Star, Sirius. Astronomers believe that Sirius B is about 19,000 miles in diameter, and Procyon B may be only 17,000 miles across. There isn't much more of Canis Minor to see with the naked eye besides Procyon. The main pattern of the constellation consists of only two or three stars, and the second brightest, **Beta (β) Canis Minoris** (Gomeisa), shines at only magnitude 2.8. This little pattern — the bounds of the constellation are technically much larger — lies alone, with Betelgeuse almost directly to its west and the compact head of Hydra the Sea Serpent almost directly to its east. In mid-March, the head of giant Hydra is just stretching over the meridian. Of all Hydra's length, only the head and one star of the neck appear above the southern hemisphere of the sky.

The last of our major winter constellations has a richness that almost rivals that of Orion. **Gemini** the Twins is named for its brightest stars, **Castor** and

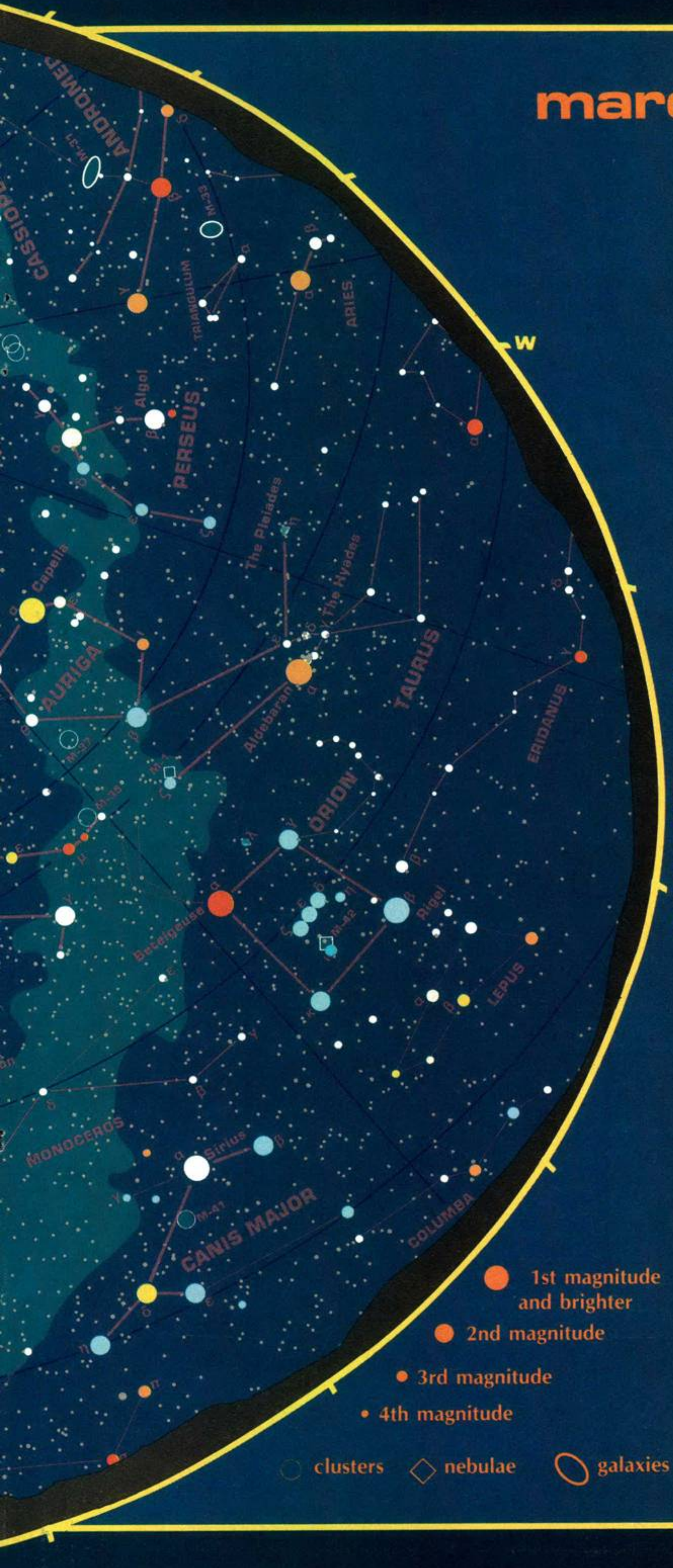
A 20-minute exposure and an 80mm telephoto lens set at f/3.5 gave Val Akins this fine shot of Venus setting over Lake Havasu, Arizona. A pinpoint image of Venus punctuates the bright trail — an effect obtained by closing the shutter for a few moments and re-opening it for several seconds.

star dome


N
E
S
Vega
M-13
DRACO
CEPHEUS
CORONA BOREALIS
SERPENS (caput)
URSA MINOR
Polaris
BOOTES
Arcturus
The Big Dipper
Mizar
M-51
M-82
M-81
M-97
CAMELOPARDALIS
Spica
M-53
COMA BERENICES
CANES VENATICI
URSA MAJOR
VIRGO
The Realm of the Galaxies
LYNX
LEO MINOR
Denebola
Castor
Pollux
CORVUS
M-66
M-96
LEO
Regulus
M-44
CANCER
GEMINI
CANIS MINOR
M-67
Procyon
CRATER
SEXTANS
HYDRA
ANTLIA
PYXIS
PUPPIS

The Star Dome shows how the sky looks at:

10:00 p.m. on March 1
9:00 p.m. on March 15
8:00 p.m. on March 31


ANDROMED
M-31
CASSIOP
M-33
TRIANGULUM
ARIES
W
Algol
PERSEUS
The Pleiades
The Hyades
Capella
AURIGA
TAURUS
Aldebaran
ERIDANUS
M-37
M-38
ORION
M-42
Betelgeuse
Rigel
LEPUS
MONOCEROS
Sirius
M-41
CANIS MAJOR
COLUMBA
1st magnitude and brighter
2nd magnitude
3rd magnitude
4th magnitude
clusters
nebulae
galaxies

march sky almanac

2nd	Tonight, the Moon will pass less than 2° north of Saturn.
5th	When it rises in the early morning hours of the 6th, the Moon will lie close to Jupiter.
6th	Last Quarter Moon is at 8:56 a.m. EST.
9th	The Moon is at apogee tonight: 251,886 miles.
14th	New Moon occurs at 1:43 p.m. EST.
15th	A very slender crescent, the Moon will lie below Mars tonight.
16th	By tonight, the Moon will have moved farther eastward to join Venus.
20th	The vernal equinox occurs at 11:39 p.m. EST. Spring begins officially in the northern hemisphere.
21st	First Quarter Moon is at 9:25 p.m. EST.
25th	The Moon is at perigee this evening: 227,060 miles.
26th	Mercury is at superior conjunction.
28th	The Moon is Full at 2:27 p.m. EST.
30th	Saturn will lie within 2° of the Moon tonight.

Don Carney braved the morning cold of January 2, 1978, to catch Jupiter setting at Pierre Lake, Washington. The bright stars to the planet's upper left are Mu and Eta Geminorum. Don used a 35 mm camera, ASA 400 film, and an exposure of 25 seconds at f/1.8 to capture this moonlit scene.

Pollux. The pair fits together nicely in the field of most binoculars and finderscopes, for they are only about 4½° apart. You should definitely be able to notice a difference in the color of these two, and it is quite obvious that Pollux is the brighter. The fact that Castor is designated Alpha and Pollux Beta has led to some speculation that Castor was the brighter when Bayer assigned the Greek letter designations several hundred years ago. A far more likely explanation, however, is that Castor has always been traditionally named (in both myth and astronomy) before his brother Pollux.

It is a mistake to neglect the rest of Gemini because of the prominence of these two stars. Castor, shining at 1.6 magnitude, just misses making the list of the traditional first-magnitude stars. But in one of Gemini's feet is a better match to Castor's brightness than Pollux: magnitude 1.9 **Gamma** (γ) **Geminorum**, also known as Alhena or Almeisan. Near the other foot is the naked-eye cluster **M-35**.

Two of the three planets discovered in historic times were found in Gemini: William Herschel spotted Uranus near Eta Geminorum in 1781, and Clyde Tombaugh located Pluto near Delta Geminorum in 1930. The discovery of Pluto was, in part, great good fortune. The area of Delta Geminorum is near one of the spots where Pluto crosses the ecliptic — the little world has a highly inclined orbit that takes it far north and south of the traditional planetary hunting-grounds of the zodiac.

Delta (δ) **Geminorum** is, by the way, one of the naked-eye stars closest to the ecliptic — so close that it is occulted each year by the Sun (several other naked-eye stars in Gemini are also very close to the ecliptic). Not far from Delta is one of the interesting naked-eye variables of Gemini. **Zeta** (ζ) **Geminorum** is a Cepheid that fluctuates from 3.7 to 4.2 magnitude with a period of a little more than 10 days. Good comparison stars in Gemini are Delta (3.5) or Kappa (3.6) and Upsilon (4.1).

Another fascinating variable is **Eta** (η) **Geminorum**, a semi-regular red giant that ranges from about magnitude 3.3 to 3.0 in a period that averages 233 days. Why not go out tonight and make your own estimate of Eta's current brightness? The variability of both Zeta and Eta Geminorum was discovered in the mid-nineteenth century by J.F.J. Schmidt, a master of naked-eye viewing.

As Gemini descends into the west, **Leo** the Lion rises higher in the east with his heart-star **Regulus** — at 1.4 magnitude, the last on the list of traditional first-magnitude stars. But Leo's month is really April, and though this impressive constellation is in a good viewing position for March, we have overlooked a zodiacal constellation between the Twins and the Lion.

Its bright neighbors make it easy to overlook dim **Cancer** the Crab. It would fare better in the dim zodiac of autumn. Cancer has its own special attraction, though, visible to the naked eye and quite striking in binoculars — the Beehive star cluster, **M-44**. We will explore faint Cancer and the other constellations now coming into view next month.

skylore

One of the ways to investigate the lore of a constellation is through the proper names of its stars. Gemini is a constellation with no less than nine stars bearing proper names. Exploring them leads us to such fascinating topics as Orion's bow and the Arabian Lion, which possibly occupied more than one quarter of the entire spring sky.

Castor and *Pollux* (Alpha and Beta). These two bright stars are of course named for the most famous twins of Greek mythology. Guy Ottewell's *Astronomical*

Gemini

Photo by Stephen A. Walther

Calendar 1981 contains an excellent discussion of Castor and Pollux lore, including the connection between the Twins and that eerie form of "slow lightning" called St. Elmo's Fire. The names Castor and Polydeukes (Greek form of Pollux) probably mean, respectively, "beaver" and "much new (or sweet) wine." The reasons for these titles are unknown, though — as usual — a topic of speculation.

Alhena or *Almeisan* (Gamma). This star is located at the feet of the more southerly twin (Pollux). Its names come from the Arabic al-Maisan ("shinings") or al-Mayasan ("strutting"); and from the Arabic al-Han'ah, which means "the brandmark" — originally applied to many of the stars of the Twins' feet and supposedly a brand found on the neck of a camel or horse.

Wasat (Delta). The name means "middle" — possibly because it is in the middle of Gemini, but more likely because it is so close to the ecliptic, the middle line of the zodiac and the middle (or at least the most important) line of the sky.

Mebsuta (Epsilon). The meaning is "outstretched," in reference to the outstretched paw of a truly immense constellation of the early Arabs. That paw (formed by Castor and Pollux) belonged to a lion, Asad, of which our present Leo forms just a very small part. Enormous Asad extended from Gemini and Canis Minor across most of the southern sky of spring, all the way to Libra.

Mekbuda (Zeta). From the Arabic for "the contracted" (that is, pulled in or retracted) paw of Asad. This paw's main part was formed by Procyon and Gomeisa (Alpha and Beta Canis Minoris).

Propus (Eta). Not Arabic, but Greek for "forward foot." Apparently the old Persian title of the star, Pish Pai, has a similar meaning. Propus is also known at *Tejat prior* — that is, the preceding (in the nightly journey west) of two stars named Tejat. But what is the meaning of "Tejat"? R.H. Allen claims it is derived from al-Tahayi, an "anatomical term of Arabia" which was "also applied to stars in the head of Orion" — apparently, then, to several compact arrangements of stars. But Guy Ottewell in the *Astronomical Companion* states that he does not know the origin of the title "Tejat" — so perhaps he is dubious of Allen's speculation.

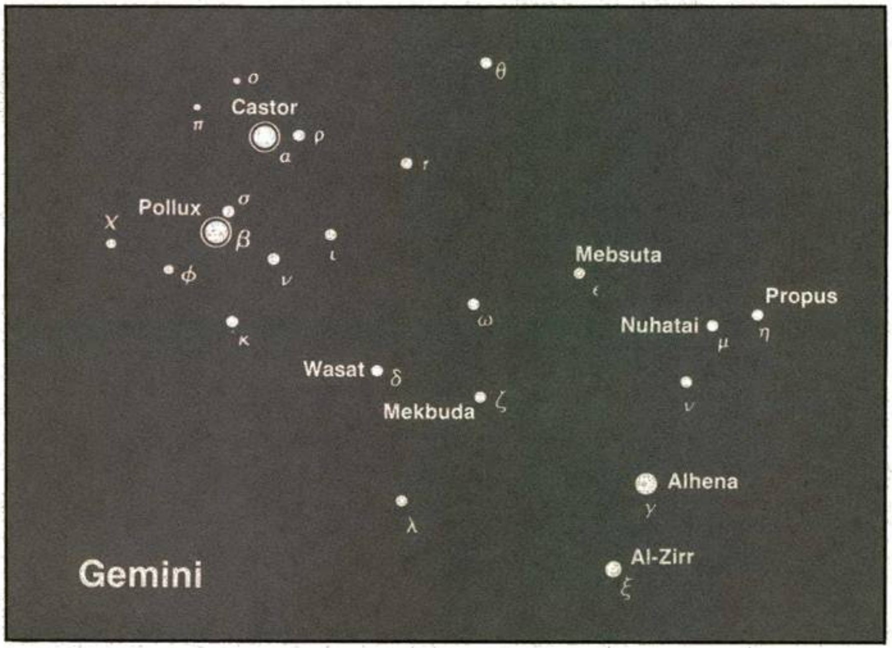
Nuhatai or *Tejat posterior* (Mu). This is the trailing (more easterly) of the two Tejat stars. It also has acquired a name from Al-Nuhatai — "dual form of al-Nuhat, a camel's hump" — a title originally applied to all the major stars in the feet of Gemini.

Allen, following Admiral W.H. Smyth, gives the color of Nuhatai as crocus yellow — one of those delightful, and sometimes preposterous, nineteenth-century descriptions of star color. We should be careful in naming these subtle tints — differences in color vocabulary, optical instruments and possibly observers' color perception all contribute to the confusion. But crocus yellow? Well, one day on a walk I saw some flowers (a type of violet, I believe) and was struck by its similarity of hue to the deep blue or purple hue of one member of the Omicron Cygni system.

The stars of Al-Nuhatai (the feet of our Gemini) also were part of Qaus al-Jausa', Orion's bow. R.H. Allen, relying on "some Arabic authority," said that other stars in this bow were Chi¹ and Chi² Orionis — stars that we now usually place in Orion's club. But George A. Davis, Jr., writing later than Allen and with better knowledge of Arabic, seems to have researched the matter more thoroughly and says that Orion's bow was formed by the feet of Gemini (Gamma, Xi, Eta, Mu, and Nu Geminorum) with the stars Epsilon, 13 and 15 Monocerotis. The three latter stars are the ones I mentioned last month as a guide to the naked-eye cluster surrounded by the Rosette Nebula. But perhaps it is better to remember the position of the cluster and nebula with reference to these three stars as the bottom of Orion's bow.

Is the bow slung over the shoulder of westward-facing Orion? No, the Arabs pictured the giant hunter aiming his bow back and up (northeastward in the sky) at gigantic Asad. Even if we find it difficult to visualize Asad, we may still add this very fine bow to the belt, sword, shield, and club of Orion.

Al-Zirr (Xi). Finally, here is a star whose name I have not seen on any published list. This is odd, considering that Allen plainly mentions it. It comes to us from Al-Biruni, a Khorasmian writer who lived around A.D. 1000, and simply means "the button."



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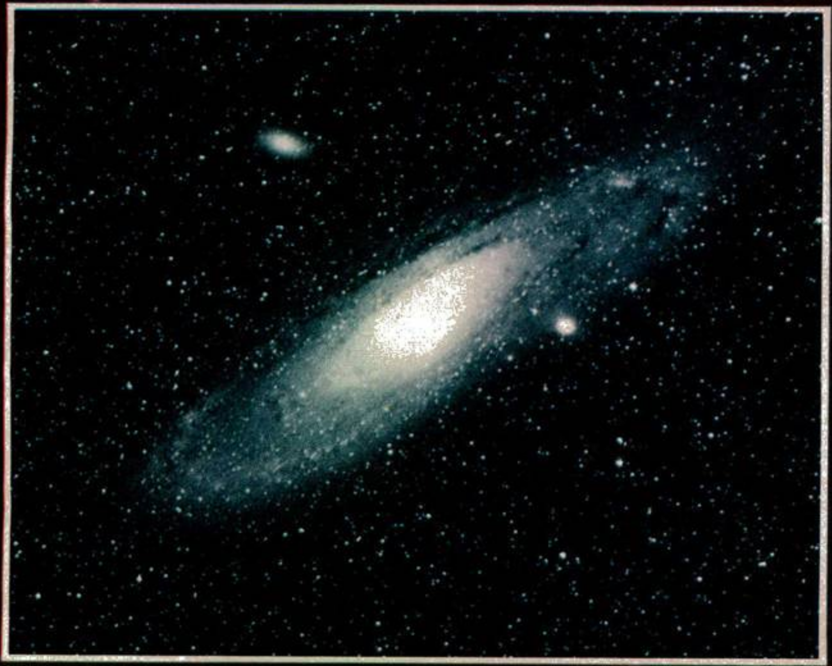
galaxy gazette | photography in astronomy

Galaxies, the basic large-scale structures in the cosmos, come in many shapes, sizes, and degrees of brightness. They are magnificient pinwheels or great balls of stars, gas, and dust. They contain networks of spiral arms, huge lanes of interstellar dust, swarms of globular clusters, emission regions and stellar associations, and sometimes violent nuclei and even interaction with other galaxies. But how much of this can we see? If you take your telescope out in the backyard and point it toward a few galaxies, you may see a slight amount of detail, but probably not very much.

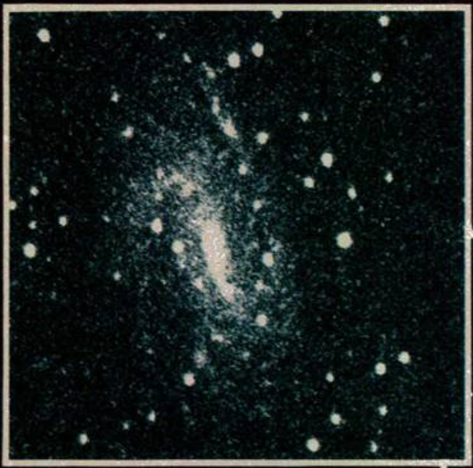
Photography, however, enables us to

M-31: The Andromeda Galaxy displays its enormous starry disk, dark lanes of dust, two principal satellite galaxies, and star cloud NGC-206. Photo by Ron Potter, who used an 8-inch f/1.5 Schmidt camera, hypersensitized TP 2415, and an exposure time of 4 minutes.

M-31

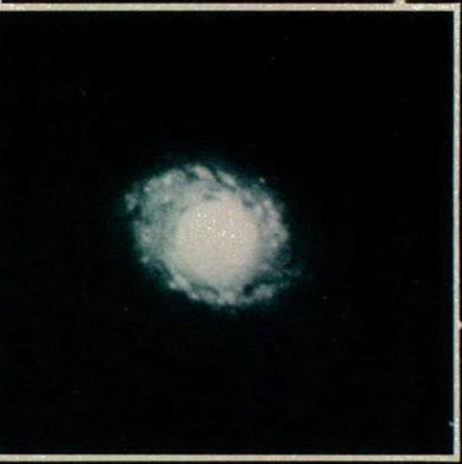


Background: Astrophotographer Brad Wallis captured the delicate blue spiral arms of the Whirlpool Galaxy (M-51) in Canes Venatici. He used a 6-inch f/6 reflector, exposing for 22 minutes on cooled Fujichrome R-100.



NGC-925

M-101



M-94

NGC-4485 and NGC-4490

Background: Bill Iburg captured the galaxy pair M-81 and M-82 in Ursa Major with an 8-inch f/1.5 Schmidt camera. He exposed for 7 minutes on Ektachrome 400 emulsion.

NGC-925: A transition galaxy, resembling a cross between a normal spiral and a barred spiral, NGC-925 lies at a distance of 21 million light-years in the constellation Triangulum. Lee C. Coombs photographed it with a 10-inch f/5 reflector and a 15-minute exposure on 103a-O film.

M-101: Evered Kreimer captured the pinwheel structure of nearby M-101 in Ursa Major using a 12.5-inch f/7 telescope and a 10-minute exposure on Tri-X film. M-101 is a face-on spiral, and floats in space about 15 million light-years away.

NGC-4485 and NGC-4490: What is this? It's a pair of interacting galaxies situated about 28 million light-years distant. The smaller, NGC-4485, is an irregular galaxy; larger and brighter, NGC-4490 is an Sc-type spiral. In this photograph — taken on April 22, 1982 — a 16th magnitude supernova is visible on the tip of the galaxy's right spiral arm. Jack Newton caught the exploding star with his 16-inch f/5 reflector and Tri-X film.

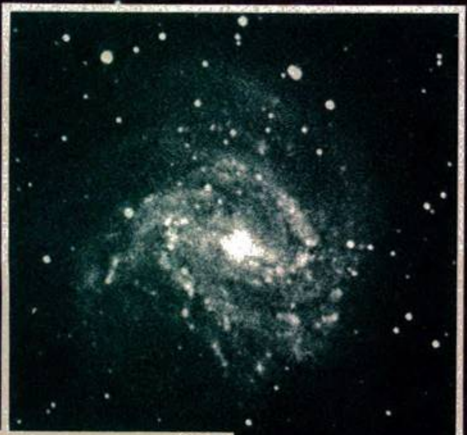
M-94: Jack Marling captured the delicate appearance of this spiral in Canes Venatici with a 24-inch f/6.5 reflector, hypersensitized TP 2415 emulsion, and a 25-minute exposure. M-94 lies about 28 million light-years away, and may have undergone a violent explosion in its nucleus several million years ago.

NGC-6946: This beautiful face-on spiral in Cepheus is a favorite for many astrophotographers. At a distance of about 14 million light-years, it is one of the closest spiral galaxies. Martin C. Germano photographed it using an 8-inch f/10 Schmidt-Cassegrain and 103a-F emulsion. The exposure lasted 90 minutes.

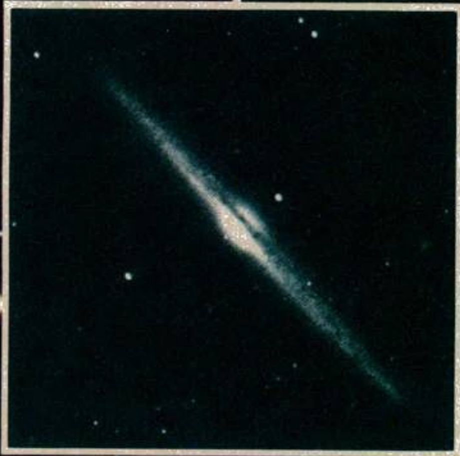
NGC-4565: Al Lilge photographed this famous edge-on Sb-type spiral, using his 12.5-inch f/8 telescope and a 120-minute exposure on 098-04 film. NGC-4565 lies about 25 million light-years away in the constellation Coma Berenices.

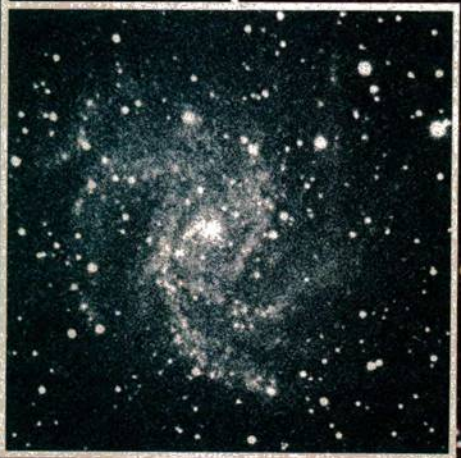
M-83: Martin C. Germano photographed the face-on Sc-type spiral in Hydra using his 8-inch f/10 telescope, 103a-F film, and a 50-minute exposure. Knotty resolution in the galaxy's arms shows large features such as starclouds, and the faint nebular glow of the outer halo is barely visible. M-83 is one of the closest spirals, at a distance of about 12 million light-years.

M-83



NGC-4565





NGC-6946

make guided time-exposures of such dim objects and thereby permanently record their shapes on film. By using your telescope as a camera and tracking against the motion of the Earth, you can record extremely faint objects with long exposures. Relatively new films like Technical Pan 2415 and techniques like hypersensitization permit backyard photographers to make portraits of the sky comparable to those made by professional observatories only several decades ago. But it isn't easy, especially at first. Only with practice in composing, focusing, guiding, and developing, can you turn out photos like these: photos that show some of the most intriguing and graceful shapes in the universe.

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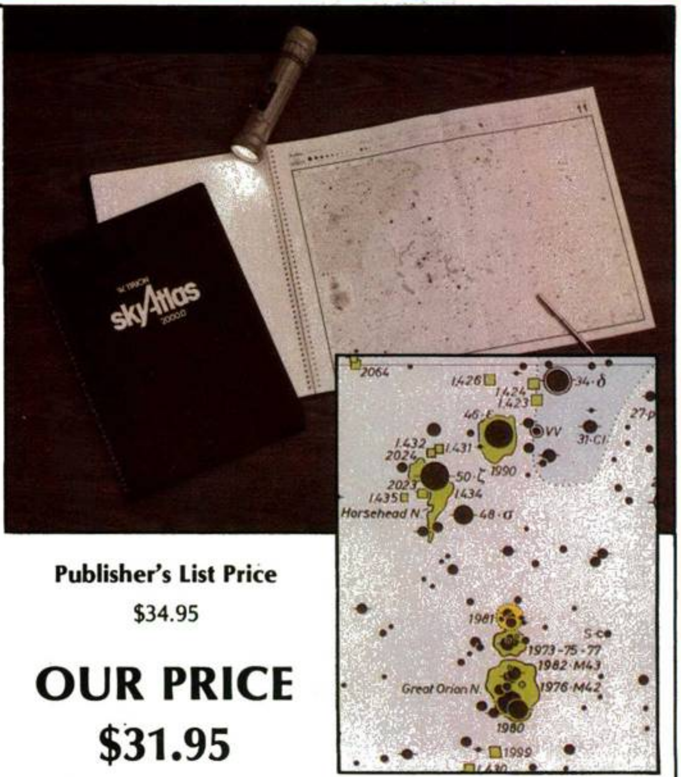
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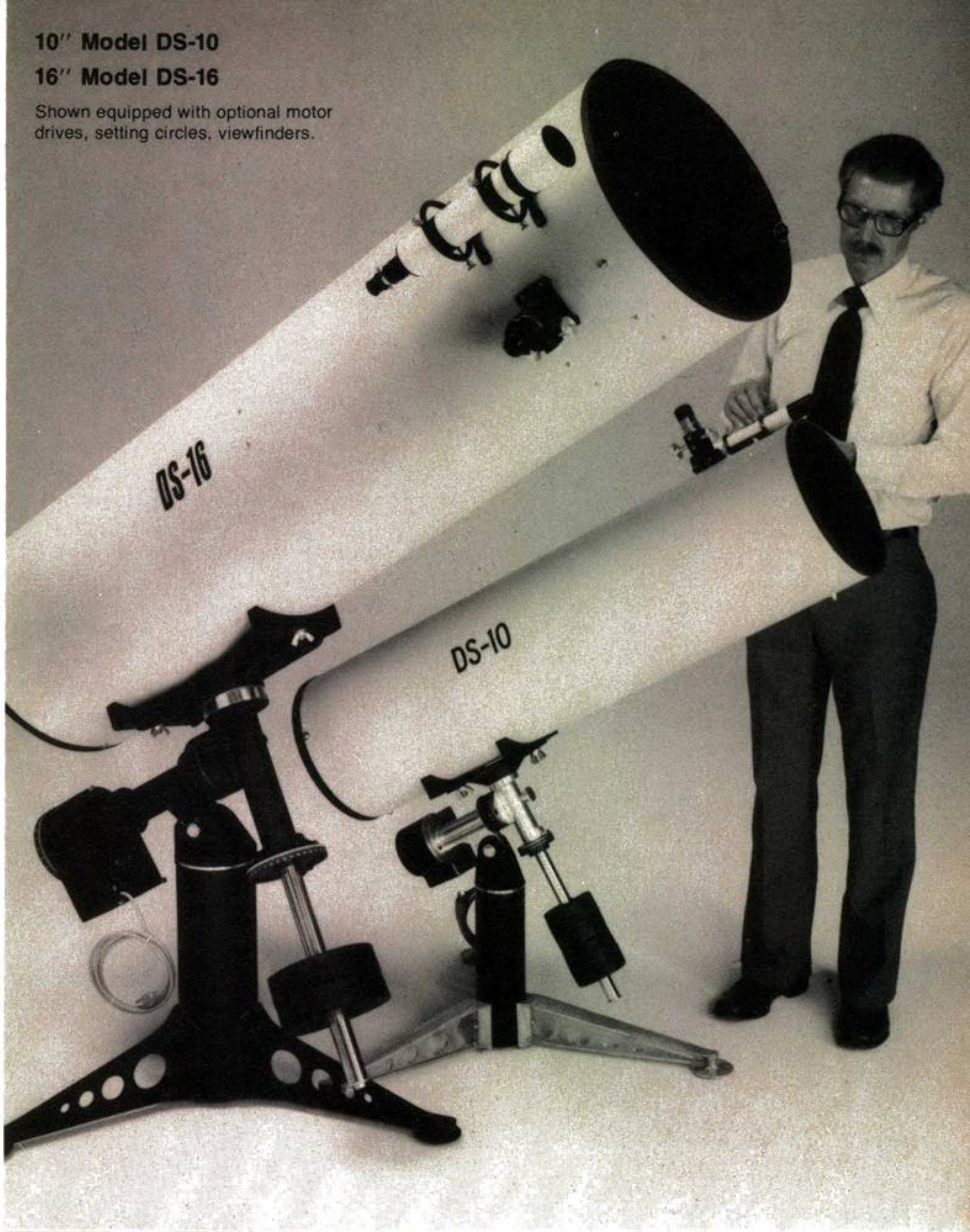
10″ Model DS-10
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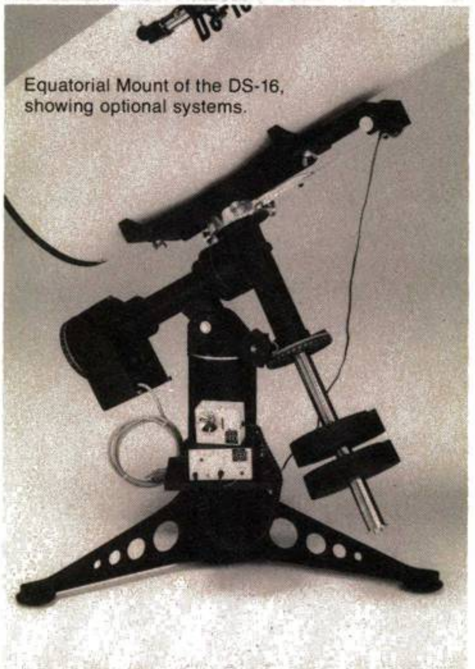
Shown equipped with optional motor drives, setting circles, viewfinders.


Equatorial Mount of the DS-16, showing optional systems.

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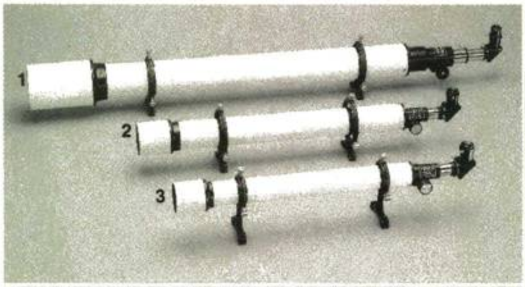
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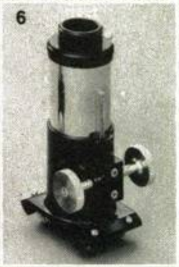
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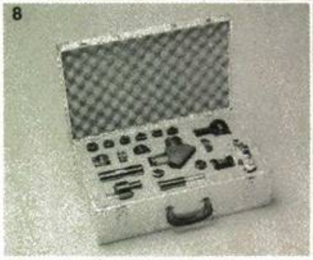
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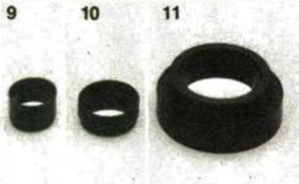
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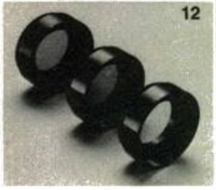
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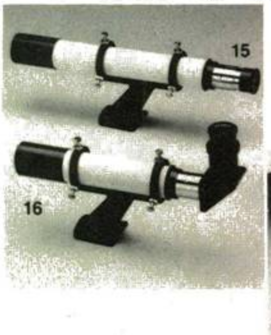
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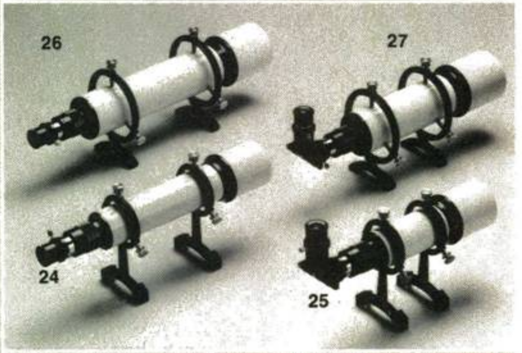
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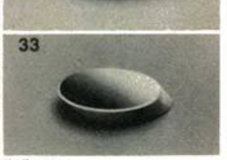
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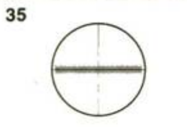
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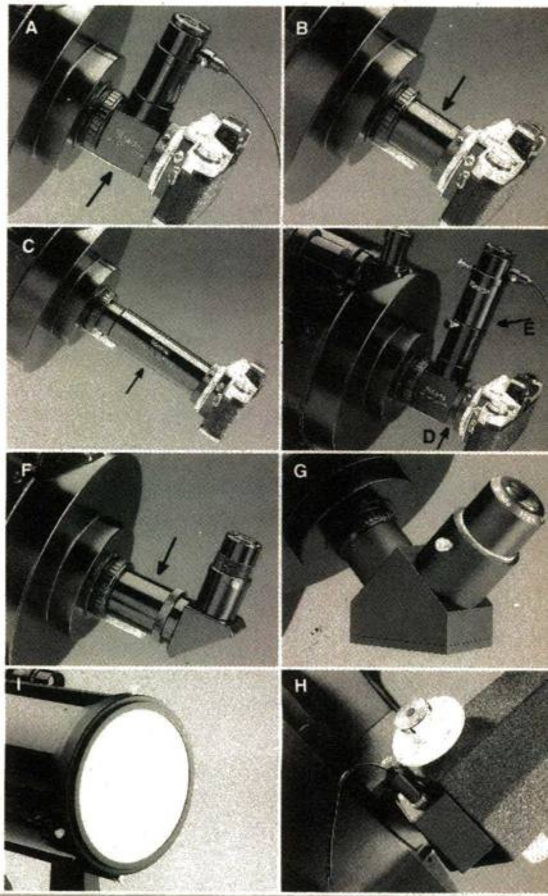

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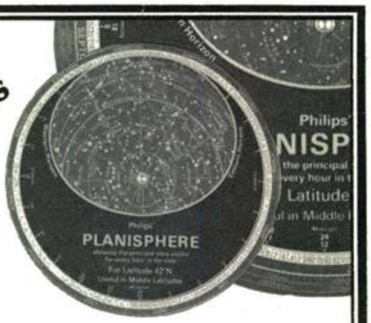

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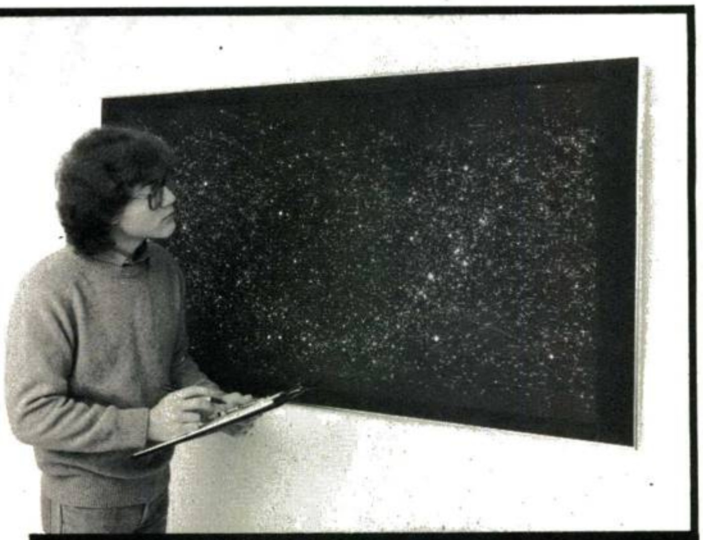

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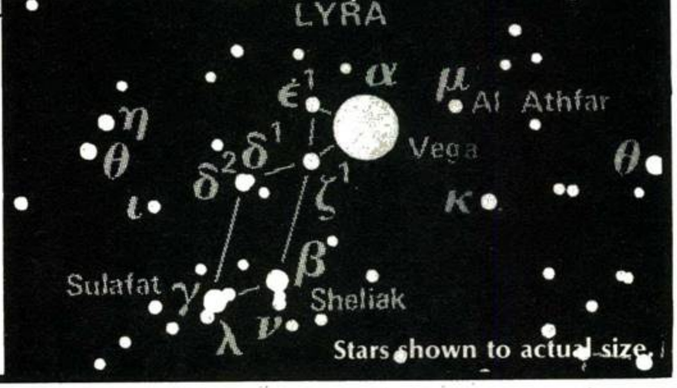

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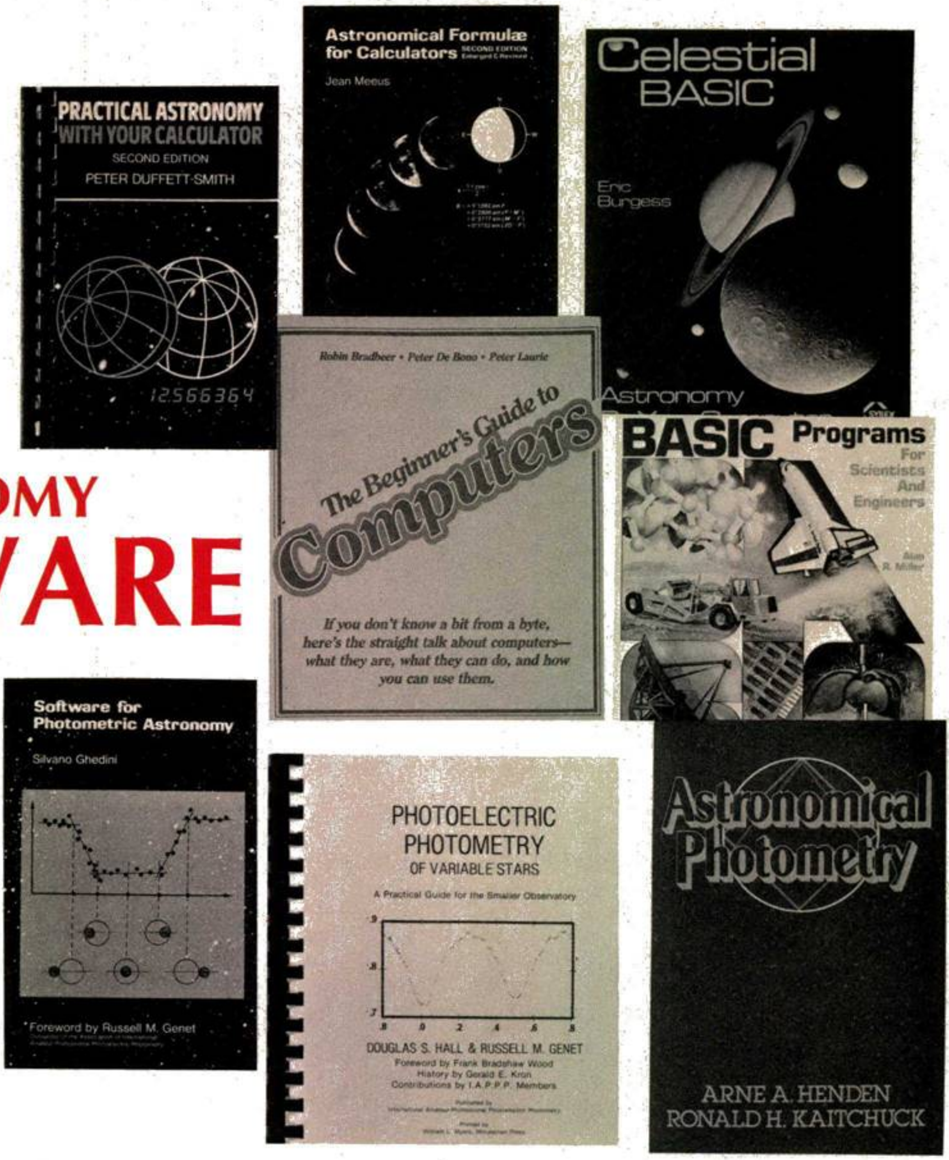
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ASTRO NEWS

Betelgeuse Soon to Supernova?

The last supernova in our part of the Milky Way occurred some 300 years ago in the constellation Cassiopeia. The remnant of this stellar explosion, called Cas A, lies 9,000 light-years from Earth and is one of the loudest radio sources outside the solar system. Examining Cas A's stellar debris helps astronomers identify stars likely to explode in the future. At least one familiar star — Betelgeuse — is a very good candidate.

When a star explodes as a supernova, most of its mass is shot radially outward at a speed of 10,000 kilometers per second — Cas A's shell of ejecta has not slowed down appreciably even after three centuries. As the shell rams into the surrounding space, it creates a shock wave that sweeps up and excites ambient gas and dust. Astronomers believe that some of this material left the star long before it exploded, so they can perform a sort of post-mortem on the remnant to find out what the now-dead star was like.

Cas A contains several bright knots of dust and gas that radiate light as the supernova's shock wave passes through. The ionized gas and tiny dust particles were probably ejected by the star toward the end of its life in the form of a powerful stellar wind. Comet tails are celestial "wind socks" blown by a similar breeze from our Sun. But the solar wind is a light zephyr compared to the gales that blow from older, more massive suns — the star that made Cas A may have been losing one-millionth the mass of Sol each year.

Material carried by a stellar wind gradually accumulates in a giant shell around the star. Typical circumstellar shells are large enough to contain all the planets of our solar system. The kind of dust produced by a star's mass outflow depends on the contents of its atmosphere, which is dictated in turn by the conditions that prevail deep within it. So by analyzing the abundance of certain chemical elements in Cas A's bright knots, astronomers get a glimpse of a star doomed to explode.

In 1978, Roger Chevalier of the University of Virginia and Robert Kirshner of the University of Michigan found about ten times more nitrogen in Cas A than the amount usually encountered in the solar system. This indicates that the progenitor star was creating energy by changing carbon into nitrogen and oxygen, which is typical of stars that have exhausted their initial hydrogen supply. So the star that made Cas A had exhausted its original internal fuel supply, was producing a large amount of nitrogen, and blew a powerful stellar wind in order to shed the excess mass that doomed it to explode.

This scenario may also apply to Betelgeuse, the bright red star that marks Orion's right shoulder. Betelgeuse is about 15 to 30 times the mass of the Sun, and the fate of such massive stars is probably to become Cas A-type supernovae. Betelgeuse also has an enormous circumstellar shell. In 1981, Michael Jura of the University of California and Mark Morris of Columbia University found that carbon was about ten times less common in the star's circumstellar shell than in the solar system. According to Jura and Morris, the same processes that produced a factor of ten deficiency in carbon should cause a factor of ten overabundance of nitrogen — indirect evidence that the outer envelopes of Betelgeuse and the progenitor of Cas A have similar compositions.

Betelgeuse is also losing a great deal of mass. Jura and Morris estimate that the star loses enough material to make our Sun every 100,000 years — a loss rate even greater than Cas A's. "The parallels between Betelgeuse and the likely progenitor of Cas A," Jura and Morris reported, "are sufficiently striking that it seems reasonable to imagine that Betelgeuse will become a supernova similar to the one that produced Cas A."

When will it happen? So far, no one can say. When Betelgeuse does explode, though, it will become a point source of illumination brighter than the Full Moon and probably visible during the day. Strangely, though, there are no historical records of Cas A's detonation — no one on Earth seems to have observed it. Dust produced by the star and dust lying in the 9,000 light-years between Cas A and Earth probably made it too dim to notice. But Betelgeuse is only 520 light-years distant — so even if "Supernova Orionis" is fainter than expected, it will still be quite a show.

Fastest Pulsar

The pulsar embedded within the Crab Nebula blinks on and off some 30 times a second and has held the title of fastest rotator ever since its discovery in 1969. But astronomers using the 300-meter radio telescope in Puerto Rico have located a pulsar rotating 642 times a second — over 20 times faster than the Crab.

A pulsar is a rotating neutron star that emits intense short bursts of radiation at regular intervals, apparently by beaming the energy like a lighthouse. Such objects would be almost impossible to identify if we did not lie in the line of sight of the energy beam. Neutron stars are the tiny, collapsed cores of stars that have exploded as supernovae.

The new pulsar, designated 4C 21.53 in the fourth Cambridge radio catalog, may contain two or three solar masses of matter compressed into an object less than three miles across — about half the size of other, longer-period pulsars. 4C 21.53 lies about 5,000 light-years distant, in the constellation Vulpecula.

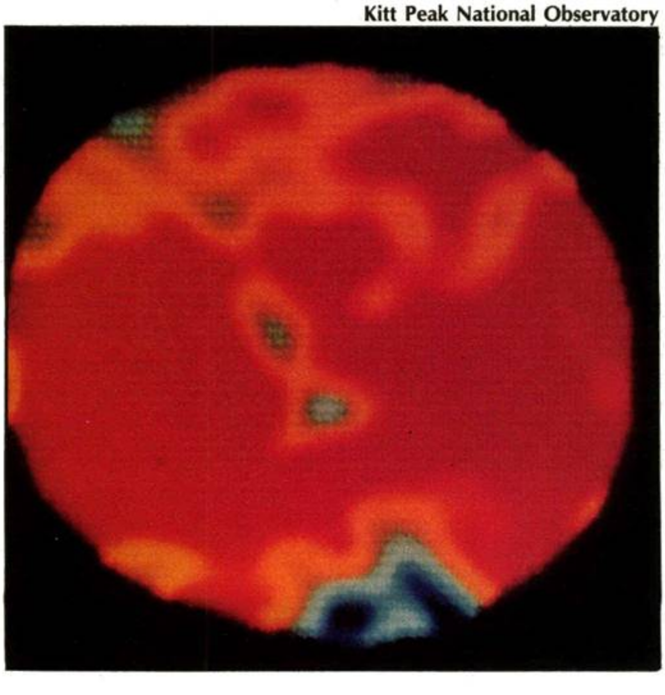
The most puzzling aspect of the new pulsar is its enormous energy output — probably 10 to 100 million times that of the Sun. So far, astronomers have no evidence of how this energy is dissipated. The object's rapid rotation is another problem for theorists: why doesn't it simply fly apart? The new pulsar's estimated mass — two to three suns — is beyond the theoretical upper limit for the formation of neutron stars: why doesn't it collapse in on itself and create a black hole?

Led by Donald Baker of the University of California, the international discovery team included Berkeley astronomers Carl Heiles and Shrinivas Kulkarni, Miller Goss of Kapteyn Laboratory in the Netherlands, and Michael Davis, head of radio astronomy at the Arecibo, Puerto Rico, radio telescope. Along with 4C 21.53's radio identification came its detection in visible light at Lick Observatory.

According to theory, the new pulsar should lose energy in the same way as the Crab pulsar — by accelerating electrons and protons to velocities near that of light. But 4C 21.53's energy should dissipate 100 times faster than the Crab pulsar, which is half the diameter of the new object and about one-third its mass. The only idea that seems to fit is that 4C 21.53 is shedding energy by emitting gravitational radiation — a form of energy that has defied attempts at direct detection, although most astronomers accept it in theory.

Over the past 15 years, astronomers have detected about 400 pulsars and have determined that 100,000 rotating neutron stars may inhabit our Galaxy.

Kitt Peak National Observatory



San Diego Votes to Abate Light Pollution

A major victory in astronomers' fight against increasing light pollution has been won recently in San Diego, California. With a population of over a million, that city is now the largest in the United States to adopt exclusive use of low pressure sodium (LPS) lamps for streetlighting. After two years of study and over two months of hearings, the San Diego City Council voted 7 to 1 for the LPS lamps, which not only cost less and use

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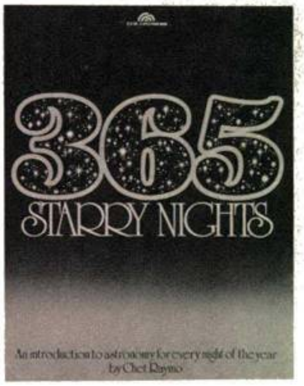

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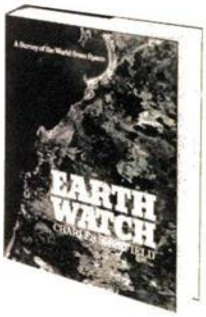

Earth Watch: Sheffield. From the snow-capped peaks of the Canadian Rockies, to the whole of Chesapeake Bay, to the narrow strip of fertile land bordering the Nile, this beautiful collection of more than 70 full-color Landsat satellite images reveals the variety and richness of Earth's landforms. A description accompanies each photograph. 155 pages, hardcover, **$22.95. Order by March 31!**

To order, use the AstroMedia order form bound into this magazine, or send to: AstroMedia Order Dept., P.O. Box 92788, Milwaukee, WI 53202 much less energy than either mercury vapor or high pressure sodium (HPS) lamps, but are vastly superior in reducing the extent of light pollution in the night sky.

Leading the struggle against the deputy city manager's report — which had recommended exclusive use of HPS lamps — were representatives of Mt. Palomar Observatory, located in northern San Diego county, as well as the Astronomy Department of San Diego State University (SDSU) and the San Diego Astronomy Association (SDAA).

During the early hearings Dr. Gerry Neugebauer, director of Mt. Palomar Observatory, had recommended a compromise solution: a combination of LPS and HPS. He admitted, however, that the 200-inch Hale telescope was operating as though it were only a 140-incher because of the existing levels of light pollution, and the council rejected the proposed compromise. Dr. Burt Nelson, chairman of SDSU's Astronomy Department, and John Mood and Mike Anderson of SDAA all recommended exclusive LPS in their testimony. But in the end, it is unclear just how persuasive this expert testimony was, since the City Council members who voted for LPS gave reasons for doing so that were essentially financial.

In retrospect, it appears that the most crucial hearings were those held by the five-member Public Safety and Service Committee. During these hearings, held prior to the full council discussions, alternatives were explored and a consensus favoring LPS was reached. The lesson in this for any other groups facing similar action is to get organized early and be persistent.

Since San Diego has led the way, astronomers struggling with the light pollution from several incorporated surburban communities around the city will have additional arguments in their continuing effort to rid the skies of unwanted and wasted light. *John Mood.*

Adrian Levesque Jr.

Sol Heats Up

Astronomers who have closely monitored the Sun's temperature over the last few years agree that it has steadily cooled since the last sunspot minimum in 1975. But now William Livingston, a solar astronomer at Kitt Peak, concludes that the Sun's temperature bottomed out early in 1981 and that its temperature is on the rise again. Livingston's research is based on observing relative strengths in a number of absorption lines in the solar spectrum. He doesn't commit himself to estimating the exact temperature change, because the data are too unspecific. But, says Livingston, "we can sense that it is heating."

The Sun varies in surface temperature because of its periodic magnetic activity cycle, which controls sunspots, among other things. The solar magnetic field reaches its greatest strength once every 11 years, causing increased magnetic activity and increased sunspot activity.

A recent hypothesis by E.A. Spiegel of Columbia University and N.O. Weiss of the Harvard-Smithsonian Center for Astrophysics accounts for this variation in surface temperature. Spiegel and Weiss propose that dark, cool sunspots repress outward heat flow from inside the Sun, and that this happens to a lesser degree all over the Sun's surface. When there is a sunspot maximum, therefore, the Sun should appear coolest to us, and when there is a sunspot minimum it should appear to be at its hottest.

Livingston's observations support this hypothesis, so it appears that we are gaining a better understanding of our home star.

Chiron

This past fall marked the fifth anniversary of Charles Kowal's discovery of Chiron, an asteroid-sized object that orbits the Sun between Saturn and Uranus. Even today, little is known about this mysterious object, and it looks as if we may have to wait until Chiron approaches perihelion in 1995 to find out much more. Astronomers have begun to make progress in pinning down a few facts about Chiron, but its central riddle — what something so large is doing where we would expect to find only comets — has not been solved.

What we know about Chiron can be summed up briefly. It orbits the Sun once every 50.7 years, has a perihelion distance from the Sun of 8.5 A.U. and an aphelion distance of 18.9 A.U. It appears to be spherical, smooth, and dark, with a diameter of 300 to 400 kilometers and an albedo of only 0.03 to 0.05.

But perhaps the most intriguing fact about Chiron is that its orbit is unstable, which means that it did not form where it is today — it must have originated somewhere else. One group of researchers found that Chiron could have been perturbed by Saturn into its present orbit as recently as 1664. Further calculations show that we can expect future perturbations, first by Saturn and then by Jupiter, that will eventually propel Chiron out of the solar system.

Kowal, an astrophysicist at the California Institute of Technology, says that Chiron appears to be in a class by itself: "After the discovery of Chiron, I continued searching for such objects for four more years. I found nothing else — so Chiron remains unique." He adds, "I suppose this isn't surprising, since Chiron has no business being there in the first place!"

Speculations about Chiron's nature have ranged from calling it a fantastically oversized comet (by contrast, the nucleus of Halley's Comet is about 100 times smaller) to an asteroid that has wandered very far afield.

Kowal says he remains convinced that Chiron "is not related to the comets or asteroids" but refuses to speculate further. He notes that Chiron, which now appears to be between 17th and 18th magnitude, will brighten to about 15th magnitude as it approaches perihelion; this may allow astronomers to determine its mass, composition, and — perhaps — its origin. *R. Lipscomb.*

X-Ray SNR

Supernova remnants are generally first identified as strong radio sources, but investigators using the now-defunct Einstein X-ray observatory believe they have discovered a previously unknown supernova remnant (SNR). Although the discovery of an X-ray supernova remnant is not in itself particularly newsworthy, the remnant discovered by Einstein overlaps a previously cataloged SNR.

T.H. Makert, of the Massachusetts Institute of Technology, and Einstein guest invesitgators R.C. Lamb, R.C. Hartman, D.J. Thompson, and G.F. Bignami discovered the source while surveying areas near gamma-ray sources detected by the Cos B satellite. They found a complex of soft X-ray emission near the galactic plane and interpret it as arising from two supernova remnants, one of which was previously cataloged as G296.1-0.7.

The group was unable to find an optical or radio counterpart of the other X-ray source, even after examining 55 astronomical catalogs and optical photographs of the region. The X-ray emission is shaped like a ring, typical of SNR. The region they examined shows evidence of great supernova activity: there are two X-ray pulsars, two radio-emitting nebular SNR, and one radio pulsar within 50 arc-seconds of the new X-ray source, now labeled 1E 1149.4-6209. "These kinds of objects," they report, "are generally believed to have resulted from supernova explosions." They also note that the line of sight intersects the Sagittarius-Carina spiral arm, so that many regions of star formation and destruction are in the same field. "Because of the morphology of the X-ray source,

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ASTRO NEWS

because there is evidence for supernova events in the vicinity, and because there appears to be no plausible alternative," the group suggests that 1E 1149.4-6209 is a supernova remnant.

The discovery of an X-ray-emitting supernova remnant with no previously detected radio or optical component suggests that many such remnants exist undetected in the Galaxy. There have been recent attempts to assume a greater supernova rate in the Galaxy (which is based on the number of radio remnants) by suggesting that many radio remnants fade below detectability sooner than their expected lifetime of about 100,000 years. The X-ray remnant may be such an object, the group notes.

Although the two SNR are probably just superimposed on the same plane of the sky, it would be significant if they were actually interacting. Markert and his team suggest that the new source might be an example of supernova "tunneling." If supernovas are very prevalent in the Galaxy, the remnants of these explosions may be close enough to interact physically. When the expanding shells of two remnants collide, the hot, ionized gases within them mix — plasma flows between them. "If supernova tunneling occurs very frequently," adds Markert, "most of the interstellar medium may consist of connected supernova remnants, not cold gas."

Space Station Studies

To better understand how humans would live and work in a permanent space environment near the turn of the century, NASA's Marshall Space Flight Center in Huntsville, Alabama, has selected four aerospace firms for negotiations leading to contracts for exploring the early uses of a space station.

The four study contracts will complement the eight space station mission analysis studies now being managed by NASA Headquarters, Washington, DC. These eight-month studies are intended to examine specific potential missions in space that could be conducted by a station permanently in orbit. With the success of the Space Shuttle test flights, NASA has begun a planning effort to define a space station for consideration by the Administration and Congress as the next major initiative in space.

The Marshall Center had recently invited the aerospace firms to propose how an early space station — one that might be in orbit by 1990 — could be used as a test facility to develop mission capabilities for a later, operational space station near the year 2000. Each of the four contracts addresses a particular area in which such an operational manned facility would play an active role.

One study area, to be examined by Boeing, will look at the role of a manned space station in building large structures — such as huge communications antennas — in orbit. A second study area, to be pursued by both Martin Marietta and TRW, will deal with the service and maintenance of satellites from the manned facility. Finally, a third study area, to be investigated by General Dynamics, will examine the relationship of the space station with an Orbit Transfer Vehicle, or OTV, for moving payloads from lower to higher orbits. The transfer vehicle could be kept in space and serviced by a manned facility.

"These studies assume that an early space station will be in orbit by 1990," said William R. Marshall, director of Program Development at the Marshall Center. "Given that premise, the studies will then suggest what kinds of experimental operations would be performed with such an early space station so that we can evolve to a fully operational station by the turn of the century."

The Marshall Center has been studying the construction of space structures, satellite servicing, and the Orbit Transfer Vehicle as separate activities. These contracts, however, call for additional research into how these activities relate to the space station itself. "What we are asking for in these new studies," said Marshall, "is to define the role of an early space station in the development of these space construction, satellite servicing, and transfer vehicle activities. The contracts will have these aerospace firms examine what experiments we need to carry out with an early space station in order to learn how to build and use most effectively a fully operational station by the end of the 1990s."

ASTRO CALENDAR

March 5	**Astrophoto V**, a one-day seminar treating all aspects of astrophotography. Moorpark College, Moorpark, California. Contact: John Byhoffer, 9406 Petit Circle, Ventura, CA 93004.
March 14-18	**14th Lunar and Planetary Science Conference** (professional meeting), NASA Johnson Space Center, Houston, Texas. Contact: 14th LPSC, Lunar and Planetary Institute, 3303 NASA Road 1, Houston, TX 77058.
April 1-3	**2nd Annual Conference on Space Development.** Houston, Texas. Contact: L-5 Society Conference, 114 Byrne St., Houston, TX 77009.
April 9	**7th Astronomy Invitational.** East Lansing, Michigan. Four-member teams meet in question-answer competition. Contact Jenny Pon, President, MSU Astronomy Club, Talbot Abrams Planetarium, East Lansing, MI 48824.
May 9-12	**6th Princeton Conference on Space Manufacturing,** co-sponsored by Space Studies Institute, Princeton University, Princeton, New Jersey. Contact: April Whitt, The Space Studies Institute, Box 82, Princeton, NJ 08540.
June 8-12	**Texas Star Party,** Fort Davis, Texas. Contact: T.S.P. '83, Dept. A, 2709 Colonial Dr., Carrollton, TX 75007. Phone (214) 242-4908.
June 13-19	**Joint Meeting of the Astronomical Society of the Pacific and the Western Amateur Astronomers,** on the Kona coast of the Big Island of Hawaii. Contact: Hawaii Meeting, A.S.P., 1209 23th Avenue, San Francisco, CA 94122.
June 20	**25th Annual Summer Science Program.** Ojai, California. Contact: Administrative Director, Summer Science Program, Thacher School, Ojai, CA 93023.
August 5-6	**Stellafane.** Springfield, Vermont. Contact: Dennis di Cicco, 60 Victoria Rd., Sudbury, MA 01776.
August 1984	**6th World General Assembly of International Union of Amateur Astronomers.** Bologna, Italy. Contact: Dr. Luigi Baldinelli, c/o A.A.B., Casella Postale 1630 AD, 1-40100 Bologna BO, Italy.

Meeting notices to appear in AstroCalendar must be submitted at least three months in advance of the meeting date. Most organizations appreciate your enclosing a long (business-size) self-addressed, stamped envelope along with your request for information.

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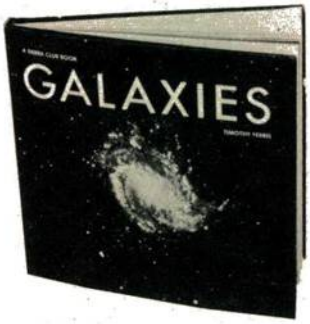
GALAXIES

by Timothy Ferris



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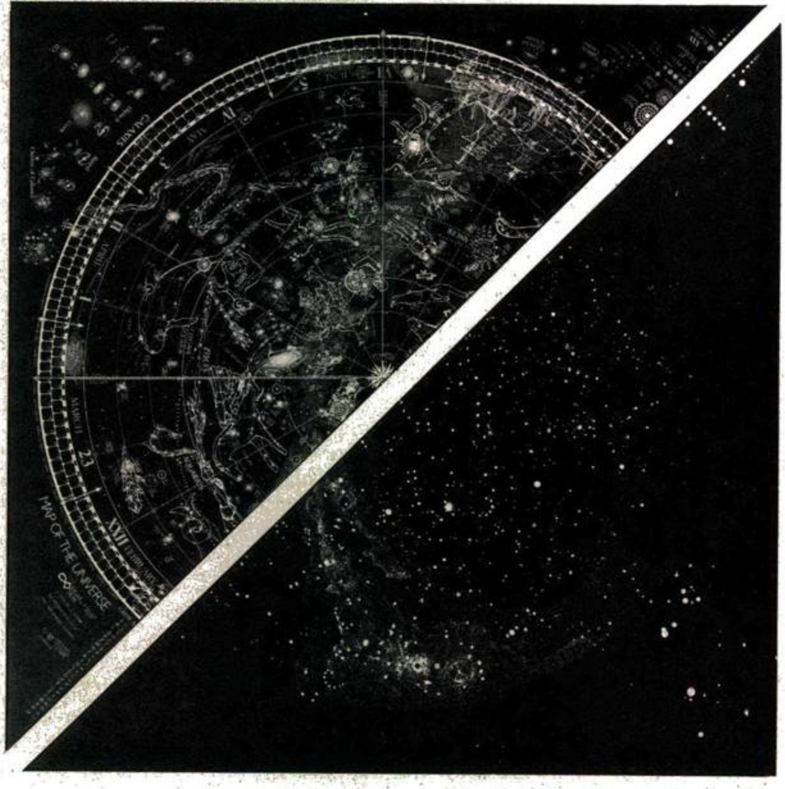

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The Curious Case of Zeta Aurigae

by David Darling

Astronomers had noticed something odd about Zeta (ζ) Aurigae as early as 1890. The cryptic legend to one of the plates of it taken in that year contained the phrases "spectrum peculiar" and "bright lines" in reference to ζ Aurigae's enigmatic spectrum. Indeed, a turn-of-the-century classification for this star read "M? G? A and F" — an object with an identify crisis if ever there was one.

Today we know that ζ Aurigae is a magnificient binary system rather than a single star with a bizarre spectrum. It consists of a very hot and luminous blue star in orbit around an enormous, and even more luminous, orange supergiant. To us, over 1200 light-years distant, it appears as an unspectacular sixth-magnitude object. But seen from within its domain, ζ Aurigae would be a wondrous sight. This strange star system promises to reveal much about the structure of massive stars in the late stages of evolution. In addition, ζ Aurigae may provide further insights into the phenomenon of mass loss from red giants and the dynamic behavior of gas in binary systems.

ζ Aurigae is an *eclipsing* binary. The component stars of its system regularly pass in front of one another as they orbit. This can only be the case if the orbital plane of the two stars lies almost parallel with our line of sight.

The alternate stellar eclipses are radically different because of the disparity in size of the system's two stars. When the smaller blue star passes behind the orange supergiant, a very obvious eclipse takes place — the blue star disappears from view and remains hidden behind the larger star for over a day. But there is no real eclipse at all when the roles are reversed and the blue star passes in front of its companion — the smaller star merely transits across the face of the supergiant.

If ζ Aurigae were just another normal eclipsing binary, perhaps our story would end here. In fact, however, the system of ζ Aurigae belongs to a select group of variable stars — the only other known members are 31 Cygni, 32 Cygni, VV Cephei, and ζ Aurigae's constellation-companion, Epsilon (ε) Aurigae.

The unusual combination of stars in these five star systems — the *marriage of a luminous, blue main-sequence star with an* aging supergiant — sets them apart from run-of-the-mill eclipsing binaries. And just why should this combination of stars be so interesting? The outermost, so-called *chromospheric* layers of the orange supergiant allow some of the light from the hot blue companion to pass through them during the partial phases of the blue star's eclipse. This rare type of "atmospheric" eclipse offers a unique opportunity to test our ideas about the structure of late-type stellar atmospheres in detail.

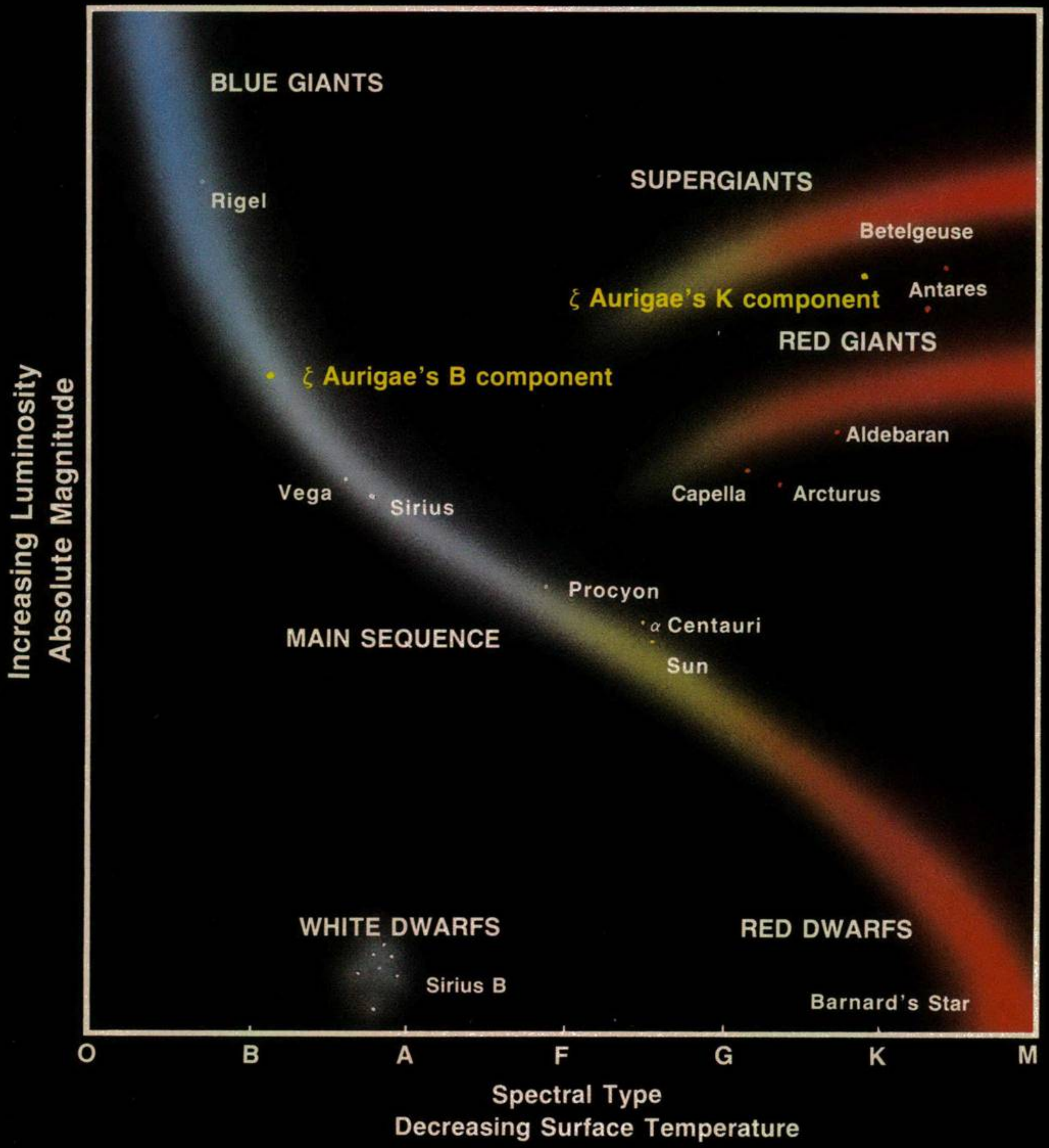
Terms like "hot," "blue," and "luminous" or "enormous," "orange," and "aging" are useful in forming a mental picture of ζ Aurigae's components. Such words are not inaccurate, merely too vague. Astronomers must know the specific nature of the system's two stars — *how* hot? *how* old? — in order to understand the processes occurring within it.

Once every 972 days, the stars of ζ Aurigae complete an orbit about their common center of gravity. Once every 972 days, Earth-based telescopes train on ζ Aurigae to observe the 1½ day eclipse of the smaller star by its far larger mate. Such regular observations of this eclipse are what has enabled astronomers to build up a composite picture of this unusual star system. For instance, the smaller component is about 5 times the size of our Sun, with a radius just over 2½ million kilometers. In contrast, the orange disk of the large supergiant star balloons out to a radius of 140 million kilometers, or slightly less than the distance between Earth and the Sun.

Size is not the only distinguishing feature of ζ Aurigae's stars. The two components differ markedly in color, and one important physical property is related to color — temperature. ζ Aurigae's smaller sun is bluish, indicating a high surface temperature — 12,500° Kelvin, according to a recent estimate. Its giant mate is far cooler, perhaps 3,500° K. Instead of using temperature or color alone, astronomers also categorize stars according to *spectral class.* ζ Aurigae's hot blue star is classified as a type B7 V, and its bloated companion is classed as K4 Ib.

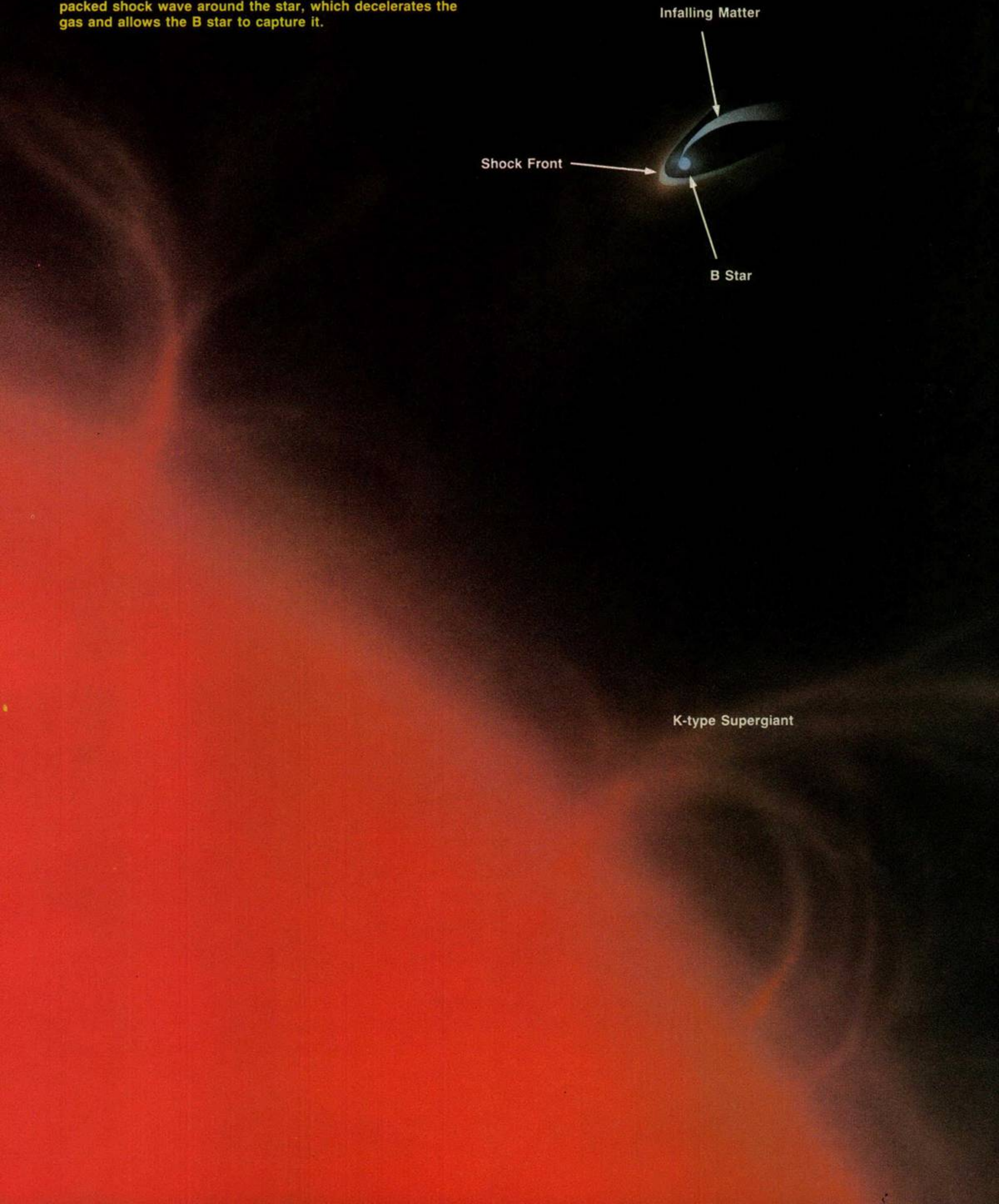
One other key quantity by which astronomers like to label stars is *absolute bolometric magnitude* — a mathematical way of expressing the total amount of radiation (including visible light) given off by a star. It represents the star's brightness at all wavelengths if it were placed 10 parsecs away. Our Sun, for instance, has an absolute magnitude of about +4. Sirius, far more luminous than Sol, tips the scales with an absolute magnitude of +1.5. Rigel is one of the most luminous stars visible to the naked eye with an absolute magnitude of -7. The greater the total brightness of the object, the lower, or more negative, is the value for absolute magnitude.

The Hertzsprung-Russell Diagram



The Hertzsprung-Russell diagram plots a star's luminosity against its spectral type. Zeta Aurigae's smaller component displays spectral lines of hydrogen, helium, iron, and magnesium atoms, which indicates a high surface temperature. The system's more massive component shows the spectral lines of molecules — one sign of a very cool star. The B-type component remains on the hydrogen-burning main sequence, while the K-type star has become a bloated supergiant and joined the ranks of Betelgeuse and Aldebaran.

Zeta Aurigae's cool supergiant constantly loses mass by blowing a stellar wind. Matter is ejected in every direction from the star's surface, and some of it is captured by the hot B star. The fast-moving material forms a hot, densely packed shock wave around the star, which decelerates the gas and allows the B star to capture it.


Infalling Matter
Shock Front
B Star
K-type Supergiant

The orange K-type star of ζ Aurigae is a very luminous object with an absolute magnitude of -4. Its smaller companion is also intrinsically quite luminous at magnitude -2. Since we know the absolute magnitudes and spectral classifications of these two stars, their respective positions on the Hertzsprung-Russell (or H-R) diagram can be plotted.

The H-R diagram plots absolute magnitude (vertical axis) as a function of spectral class (horizontal axis). Several distinct regions appear in this plot — regions where the majority of known stars tend to fall. Winding its way across the center of the diagram is an area called the *main sequence*, which contains normal "middle-aged" stars. Main sequence stars create energy by fusing hydrogen nuclei into helium nuclei within their cores. Our Sun is near the center of the main sequence. Alpha Centauri, Sirius, Rigel, and the blue sun of ζ Aurigae all lie on the main-sequence "highway."

To the upper right of the main sequence is a region that contains extremely luminous stars with very low surface temperatures — the giant and supergiant stars. The orange component of ζ Aurigae belongs here. Astronomers can deduce two things from its placement in this region. First, the star must be either a red giant, or a modest supergiant. Second, giant stars like ζ Aurigae's orange component have used up their central supply of hydrogen. Thus astronomers know that the system's K-type component has left the main sequence to enter its final stages of evolution.

All of this raises an interesting question. Since both stars of the ζ Aurigae system presumably formed around the same time from the same primordial gas cloud, they should be in similar stages of life. But this clearly is not the case. The K-type supergiant has attained bloated senility with its main supply of nuclear fuel exhausted, while its companion stubbornly retains a youthful status on the main sequence. What could cause the supergiant to age faster than its stellar mate? The supergiant is eight times more massive than our Sun — about two solar masses heavier than its stellar sibling. The more massive a star, the faster it will consume its primary energy source and the more rapidly it evolves.

In short, we know that ζ Aurigae is an eclipsing binary system in which a hot, blue B-type star orbits a somewhat more massive and much larger orange supergiant. The blue star still occupies a position on the main sequence of stars burning hydrogen in their cores, while its larger companion, less thrifty with its hydrogen, has become a red giant in its final stages of life.

The system is an example of a small class of objects called "atmospheric" eclipsing binaries. But what exactly does this mean? The orange supergiant, while massive, is also extremely luminous. Indeed, this star is so large that 8 million stars the size of our Sun would fit inside it. Given such a huge volume in which to contain its eight solar masses of material, ζ Aurigae's K-type component must have a low average density. More specifically, the star's outer layers are extremely tenuous, so thin that they fail to block out all the light from the B-type companion as it slips behind the supergiant. The blue star passes behind progressively denser layers of the K star, and eventually it is hidden completely behind the orange supergiant for just over a day. After eclipse, the blue star emerges from the opposite limb of the huge orange disk, and its brilliant light once again begins to shine through the tenuous chromosphere of the supergiant.

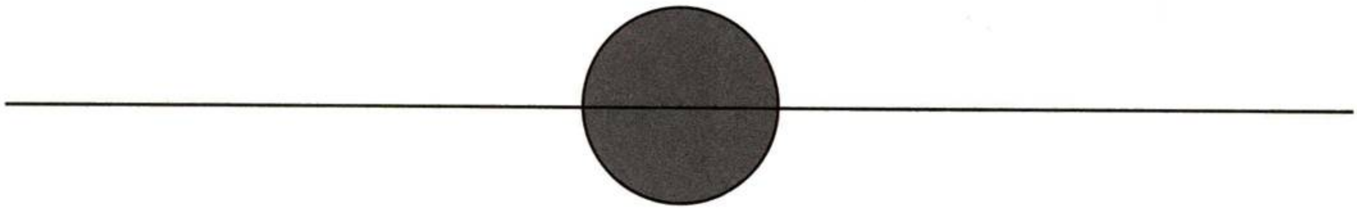
Stars with extended atmospheres, like the supergiant of ζ Aurigae, can transmit light from a background source through their rarified outer layers. From an astronomer's standpoint, the exciting thing about this system is that the small B-type star acts as a precise, almost point-like probe of the K star's outer atmosphere. By watching the behavior of ζ Aurigae's combined spectrum during the critical partial phases of an eclipse, researchers can study the structure and behavior of the supergiant's chromosphere in detail.

Like all stars, the B star of ζ Aurigae radiates energy into space at many wavelengths, mostly in the form of *continuum* radiation. Before and after total eclipse, the smaller star passes behind the various atmospheric layers of the supergiant and beams its light through the thin gas of the giant star and on to Earth. The uppermost material in the supergiant's atmosphere, tenuous though it is, alters the blue star's light. Atoms and ions in the supergiant's chromosphere absorb light from the B-type companion's continuum at very specific wavelengths, creating dark absorption lines superimposed on the continuous background spectrum.

Elements in the blue star's own upper atmosphere absorb some of this continuum radiation, also creating absorption bands. But astronomers have determined the individual spectra of the component stars when they are well separated from one another, so they know which absorption lines are formed by the B star's atmosphere and which lines are generated by the upper layers of the supergiant. The density of the obscuring material can be determined by measuring the intensity of these lines. And the displacement of the lines from their positions found in laboratory spectra indicates the velocity of the absorbing chromospheric matter. So much information from a trickle of light that began its journey to Earth when Charlemagne ruled!

Astronomers have learned some interesting things by probing the stars of ζ Aurigae. For example, the chromosphere of the orange giant is far from being static or homogeneous. The K star's atmosphere contains rapidly moving (up to 24 kilometers per second) high-density concentrations in the tenuous atmosphere. Some astronomers have interpreted these large-scale mass motions in the supergiant's upper layers as evidence for supersolar prominences. Others have cited the fast movement and "clumpiness" of material in the outer atmosphere as evidence of turbulence, a phenomenon that may play a key role in the chromospheres of old, massive supergiants.

Another vital piece of information gleaned from the atmospheric eclipses of ζ Aurigae relates to the supergiant. Mass



Distance	**approximately 0.4 kpc (=1300 light years)**
Orbit	
Period	**972.2d**
Inclination	**approximately 90°**
Maximum separation	**about 350 million miles (560 million km)**
Minimum separation	**about 125 million miles (200 million km)**
Duration of eclipse	
Total	**37d**
Atmospheric (either side of total)	**1.5d**
Next eclipse begins April 1985	

Larger Component		**Smaller Component**
K4 Ib (Yellow-orange)		**B7 V (Blue-white)**
about 3,500 °K	**Surface temperature**	**about 12,500 °K**
about 200 $D_\odot$	**Diameter**	**about 5 $D_\odot$**
about 8 $M_\odot$	**Mass**	**about 6 $M_\odot$**

loss in the form of stellar winds is normal for massive stars in advanced evolutionary phases. Even on purely statistical grounds this must be so. Stars that remain heavier than 1.4 solar masses cannot evolve to the white dwarf stage and end their days in a cataclysmic supernova explosion. But there are far more stars above the "white dwarf mass limit" than there are supernovae. Since many stars reach the red giant stage with masses greater than 1.4 suns, astronomers are left with an inescapable conclusion that most, if not all, red giants must shed mass in order to squeeze below the critical mass at which supernovae occur. And the most obvious mass-loss process is that of stellar winds.

But does the supergiant of ζ Aurigae show signs of having a stellar wind? Certain additional absorption lines appear to originate in an expanding cloud of low-density material surrounding the K star — excellent evidence for a stellar wind. Material blown from the star by the wind would naturally form a circumstellar halo of gas and dust (see "The Vanishing Act of Carbon Giants," ASTRONOMY, June 1982). Estimates of its strength vary, but according to a recent study conducted by Robert Chapman of NASA's Goddard Space Flight Center, ζ Aurigae is losing matter at the rate of 2×10^{-8} of a solar mass per year. That is, the K component loses an amount of mass equal to our Sun's every 50 million years.

What happens to the matter blown from the surface of the supergiant by its stellar wind? The material could never fall back to the K star's surface; stellar winds typically blow at 95 to 110 kilometers per second — well over the escape velocity of a bloated supergiant. Some of the material escapes into interstellar space to help replenish the Milky Way's supply of raw material. New stars may eventually form from matter lost by the supergiant. But a small fraction of the material blown by the stellar wind through the ζ Aurigae system meets with a different fate — it is swept up and absorbed by the small B-type companion.

The stellar wind forms a shock wave as it flows from the orange giant past the blue star. Fresh material carried out by the wind is deflected by this shock and piles up behind the blue star along the axis of the shock. Now concentrated and slowed down, the dense column of ex-supergiant matter falls onto the surface of the smaller companion. A lot of star-stuff is accreted in this way. Surprisingly enough, the amount of material gained by the blue companion in a single decade is roughly equal to the total mass of its photosphere. Making the reasonable assumption that the supergiant has been spraying off matter in its stellar wind for at least the last million years, the B star of ζ Aurigae must have a photosphere composed almost entirely of its larger companion's material.

To artists and poets, the double star system of ζ Aurigae offers plenty of food for the imagination. But to scientists as well, this binary is a very special object. Unusual phenomena abound in this intriguing system, and astronomers will continue to look to ζ Aurigae for clues in the complex puzzle of stellar evolution.

David Darling holds a Ph.D. in astronomy from the University of Manchester (U.K.) and is a computer consultant and a freelance science writer. His last article for ASTRONOMY was "Molecules in Space," in the March 1982 issue.

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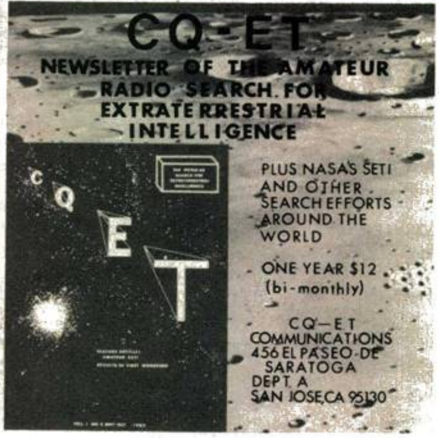
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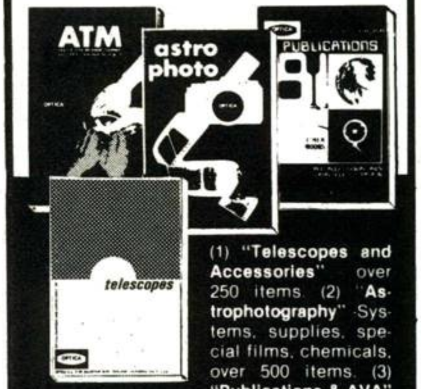

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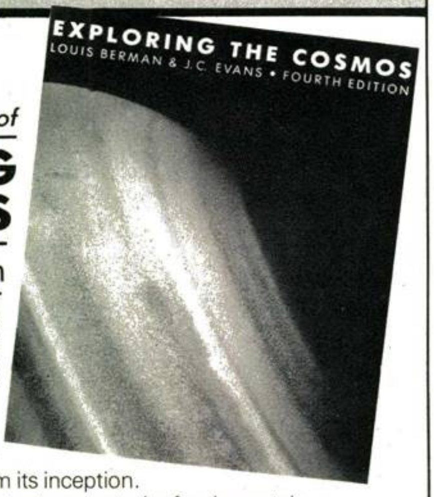

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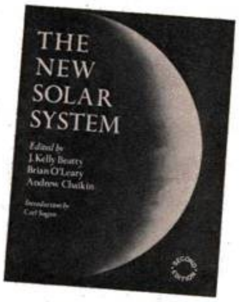
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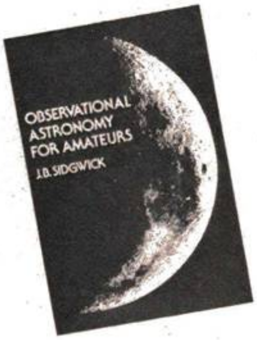

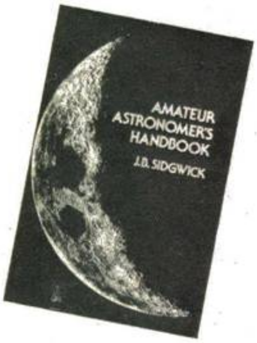

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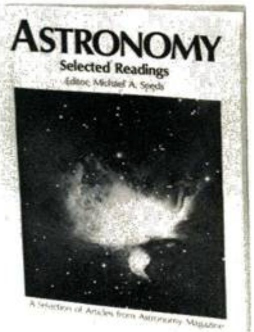

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backyard radio astronomy

equipment atlas

by
John Potter Shields

During the past several years, amateur astronomers have become increasingly interested in the field of radio astronomy. Using equipment that often costs less than a conventional optical telescope, these observers have "watched" great solar flares, listened to fascinating sounds from Jupiter, "seen" the radio noise from the center of our Galaxy, and detected extragalactic radio sources. Radio astronomy, to the uninitiated, seems forbidding, technical, and beyond all hope. Yet it's not — though it it takes effort and a willingness to learn. The reward of seeing a wiggle appearing on your chart recorder — a wiggle that you know represents signals that originated millions of light-years away — quickly repays the work and study.

Let's take a look at the basic principles of radio telescopes first, and then we'll go on to look at the construction of several practical amateur radio telescopes. If you know nothing at all about radio or electronics, it helps to talk to a friend who's a ham radio operator or knows a resistor from a diode, and to whom the term DIP means "dual in-line package."

What Is Radio Astronomy?

Before going further, let's first see what radio astronomy is. To begin, while optical astronomy deals with light waves from objects in space, radio astronomy deals with radio waves. In optical astronomy, you detect electromagnetic radiation with a wavelength of about 1/50,000 of an inch, or 500 nanometers. Radio astronomy deals with radio waves from a celestial source, electromagetic radiation with a wavelength of a few inches to many feet (a few centimeters to tens of meters). In both cases, the instrument used to gather and focus the radiation is called a telescope.

However, there is a big difference between optical and radio telescopes. As we all know, the major component of any optical telescope is the mirror, which is responsible for its gathering light from the observed source. In the case of the radio telescope, the antenna serves as the gathering device — in this case, for radio signals. As you have probably noticed, the signal gathering parts of radio telescope antennas are quite large. This is due to the much longer wavelength of radio. It's a matter of physics that the size of the signal-gathering reflector is a direct function of the wavelength: the longer the wavelength, the larger the reflector must be.

The Basic Radio Telescope

The Antenna. The most basic type of radio telescope is technically referred to as a "radiometer." This consists of three basic components: an antenna, a receiver, and an indicating device or readout display.

The antenna can almost be considered as the "heart" of the radio telescope. It is the antenna's job to gather the extremely weak galactic and extra-galactic radio signals and feed them into a wire. The antenna must be large due to the long wavelengths involved. However, aside from size, there are several other important requirements for the radio telescope antenna. First, the antenna must have a narrow beamwidth — that is, it must detect radio energy coming from only a small part of the sky. If the antenna cannot resolve closely spaced objects, this will limit the effectiveness of the system. In general, but not always, the larger the antenna, the narrower the beamwidth. (This is analogous to an optical telescope's ability to split double stars.)

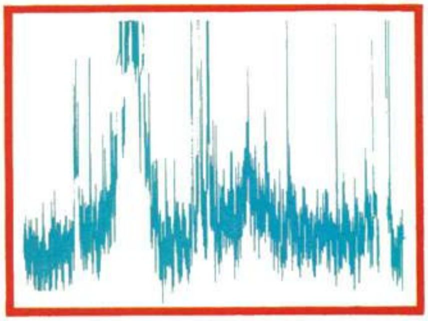
Second, the antenna should receive over a wide bandwidth. Since radio signals from space are in the form of "radio noise," it is desirable that the antenna *not* select a narrow range of wavelength, but receive them all well. It is a matter of physics that the received signal intensity or "noise power" is a direct function of noise bandwidth. Thus, the wider the antenna's bandwidth, the larger the signal power received. (By way of comparison, imagine an optical telescope that would only image red light. It wouldn't be very useful.)

Finally, it should have a large collecting area. The larger the radio telescope's effective antenna aperture, the greater the "surface" facing the radio source, and the more energy received. (The same is true of optical telescopes — the bigger the mirror, the better.)

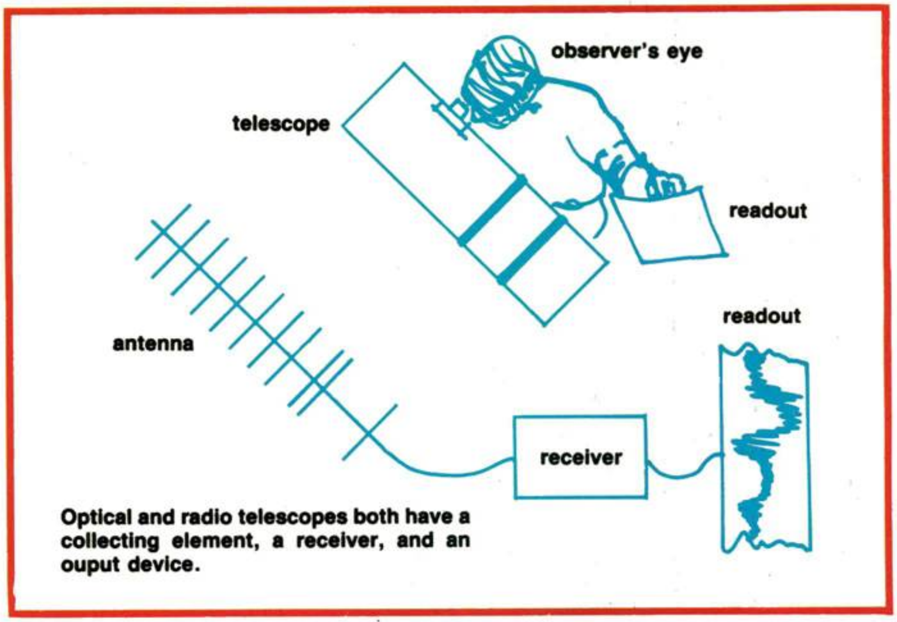
The Receiver. Next, we'll turn our attention to the radio telescope's receiver. The receiver's job is to convert the radio energy collected by the antenna into an electrical signal. As with the antenna, there are a number of requirements for the radio telescope receiver.

First, a radio telescope receiver must have sufficient sensitivity to receive the extremely weak extraterrestial radio signals. These range well below 1 microvolt. As a result, most large radio telescopes use special nitrogen-cooled parametric receivers. (You need sensitivity in optical astronomy, too — your eye, for instance, must become dark-adapted before you can see much.)

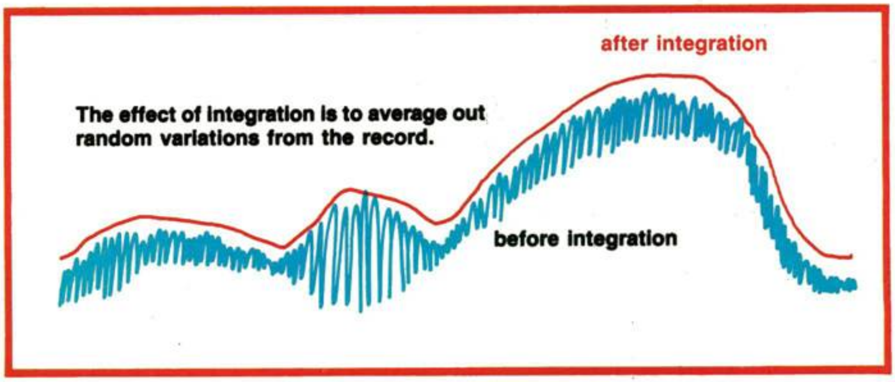
Second, receivers must have a low internal "noise" level. Since we are dealing with extremely weak signals, it is important that the receiver not hide the signal with false signals generated inside itself. "Low noise" means that the receiver will not mask out the received signal.



A chart recording of a major solar flare made June 5, 1982, using the simple radio telescope shown in this article.



Optical and radio telescopes both have a collecting element, a receiver, and an ouput device.



The effect of integration is to average out random variations from the record.

(Similarly, you couldn't take astrophotos if the inside of your camera glowed in the dark.)

Third, the receiver needs a wide bandwidth. The wider the range of frequencies detected, the greater the noise power received. Since you are dealing with the received noise information, it's obviously important that you have a receiver with wide frequency bandwidth. (If you could only see red light, you'd see fewer stars.)

Fourth, the receiver must be stable. Since radio astronomy deals with variations in a received signal, we can't tolerate "receiver drift" as this would mask out or overwhelm real signal variations. (Imagine the ASA speed of your favorite astro-film changed capriciously from one minute to the next. Result: few good pictures.)

Back-End Device. Attached to the output of the receiver is the integrator. This device, a simple electronic circuit, smooths out the rapid variations in the received signal, averaging them over several seconds to several minutes. A choppy, changing signal goes into the integrator, but a fairly smooth average power level comes out of it.

Readout Device. In its simplest form, this may consist of a sensitive meter. You simply read it from time to time and write the numbers in a log. A strip chart recorder is a step up in sophistication — it provides a continuous graph of the integrated, received signal. Very sophisticated readout systems use computers to sample and enhance the signal for display.

Building Your Own Radio Telescope

Now that we've examined some of the principles of radio astronomy, let's turn our attention to the construction of two amateur radio telescopes. There are, of course, quite a range of telescopes that can be built, but it's best to start with something simple with a proven record of working well, like the basic flare monitor that I built.

A solar flare monitor provides a lot of interesting information on day-to-day solar flare activity. It also detects the strong and extended radio source at the center of our Milky Way Galaxy. The arrangement of the solar flare receiver is straightforward, consisting of the three basic components: antenna, receiver and readout.

The antenna is an inexpensive ($29.95) 10-element FM antenna bought at Radio Shack. I mounted the antenna on a stepladder by means of a small metal bracket and simply tilted the antenna up to "see" the Sun. The output from the antenna is connected to the receiver by means of a length of RG/59U coaxial cable.

The FM receiver need not be expensive — even one of the department-store variety will do nicely. Its output is connected to an integrator network, which is designed to smooth variations in the output noise signal. I assembled my integrator in a small metal box, which I obtained at Radio Shack. Assembly of this unit is not critical, with simple point-to-point wiring being used.

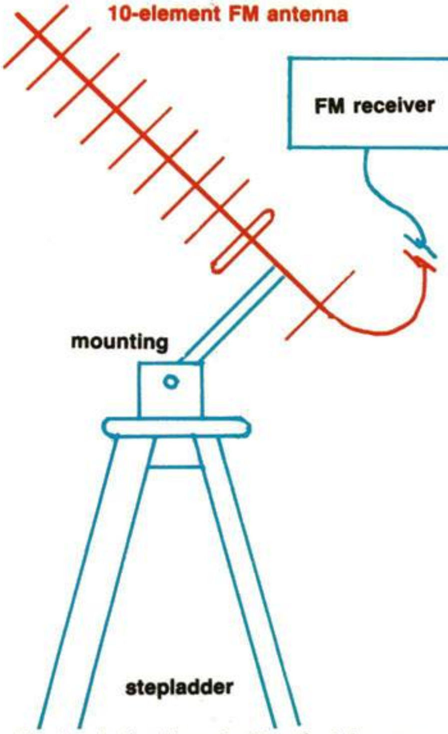
The simplest signal readout can be a 0-50 microamp DC meter connected to the output terminals of the integrator. If you can, however, you should use a strip chart recorder to provide a permanent record of the received signals. While commercial strip chart recorders are quite expensive, Rustrak Corporation offers recorders in the $110 range. Another possibility is to contact a local high school or university, telling them about your project. Under the right circumstances, they might be willing to lend you one.

Operation. Turn the power on and allow the receiver to stabilize for about 30 minutes. With the antenna disconnected, connect a 50-ohm resistor across the input terminals of the receiver and note the output reading on the meter. The purpose of this resistor is to establish a zero reference point.

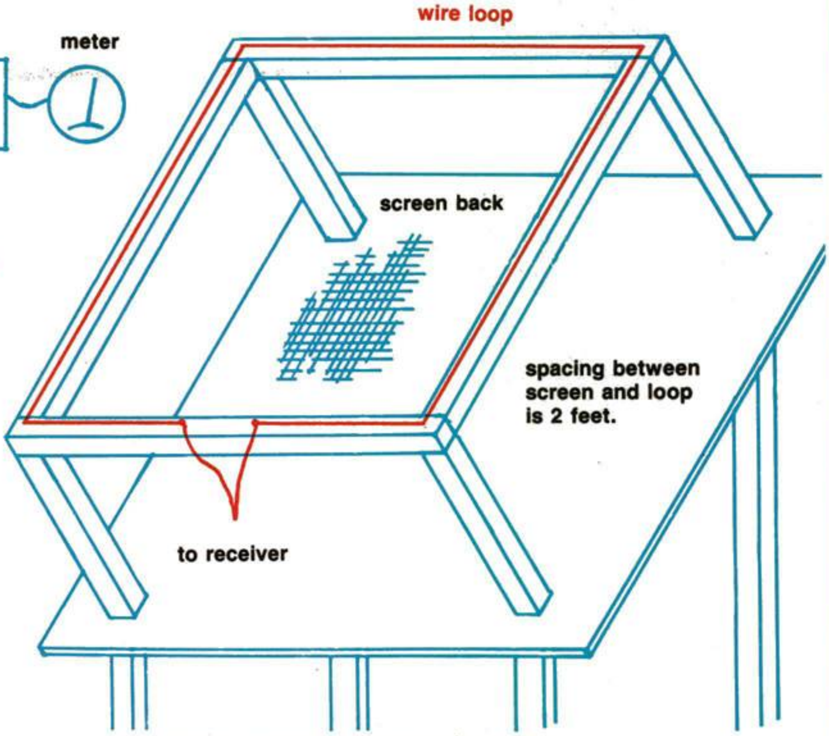
Point the antenna due south. Remove the resistor from the antenna terminals and connect the antenna leads. You should note a slight increase in output meter reading — this indicates that your system is operating.

The next test is to monitor solar activity. Due to the approximately 30° beamwidth of the 10-element antenna, take a whole series of measurements between 10 a.m. and 2 p.m. While normal solar activity will produce only a slight increase in output signal, if a flare occurs you will see a significant increase in the output signal level.

Your radio telescope's sensitivity can be increased by the addition of an RF pre-amplifier at the antenna terminals. A suitable antenna-mounted pre-amp is the Radio Shack (part number) 15-1134. This unit provides a fair degree of amplification, and helps compensate for losses in the cable connecting the antenna

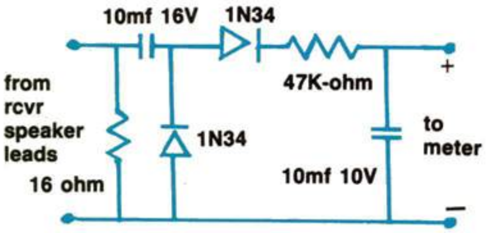


The basic "radiometer" radio telescope for detecting solar flares. The antenna is mounted atop a step ladder.



A wire-loop antenna is extremely easy to build. Each side of the loop is 5 feet long.

Circuit diagram for an integrator. This circuit is simple to assemble and placement of components is not critical.



to the receiver.

Monitoring Additional Sources. Even the most basic receiver is capable of receiving more sources. For example, the center of the galactic plane (Milky Way) will provide a consistantly strong signal. Incidentally, because of its constancy, this signal makes an ideal reference source.

Receiving Signals from Jupiter

Jupiter and its satellite Io interact to produce very interesting radio emissions that sound much like rolling sea surf or distant thunderstorms. The receiver described here is easy to construct, and provides interesting output signals.

The receiver consists of two basic components: the receiver and a loop antenna. No indicating meter or chart recorder are needed, although you might want to use a tape recorder to record these unusual signals.

The Receiver. Due to the relatively intense signal from Io, an ordinary amateur radio communications receiver can serve well for the receiver. Its only requirements are that it have reasonably good frequency selectivity (i.e., a narrow bandwidth) and be capable of tuning from 20 to 25 MHz. Note that because the signal is narrowband in this particular case it is necessary to use a narrow bandwidth receiver.

The other part of the telescope is a loop antenna which consists of a square loop of wire, 1/8-wavelength on a side, mounted on a wooden support frame. Behind the loop is mounted a screen reflector slightly larger than the loop. Connections to the receiver are made by means of a length of RG/59U coaxial cable.

Operation. Io's signals occur on a more or less random basis, so that it is pretty much a "catch as catch can" receiving process. Bear in mind that this may actually be helpful: you will be able to recognize the Jupiter/Io signal because it will be something quite new after a period of seemingly fruitless monitoring!

The best approach is to place your antenna in a position so that it will "see" Jupiter as it travels across the sky. Due to the broad beam of this antenna, approximate aiming will suffice. To operate the system, when Jupiter is up, adjust the antenna to point at it and switch on your receiver. Carefully tune your receiver through the frequencies between 20 to 25 MHz, listening carefully. If Jupiter and Io happen to be radiating a signal, you will readily detect it by its peculiar "waves-on-the-beach" sound. It is necessary to tune to find the signal because Io and Jupiter do not transmit on any one specific frequency.

What Next?

Radio astronomy *is* a pretty technical branch of astronomy. As you get into it, you'll find you're learning more and want to do more. You might want to build an interferometer, a two-antenna radio telescope that gives you the resolution of a large antenna without the sheer size of a big antenna. You might want to build a dish antenna. You can begin the learning process by reading more about the subject and continue it by meeting and talking to radio hams and other amateur astronomers interested in radio astronomy. It's up to you. One thing is for sure: you'll know it's worth it when you see the signal from Cygnus-A on your charts!

the backyard astronomer

puppis

Mercury

If you spot Mercury at all during March, it will be only in the first few mornings of the month. After that, the planet will move too close to the Sun to be seen. It will reappear in the evening sky during the first week of April.

At superior conjunction on March 26th, Mercury will be 1.35 astronomical units (201 million kilometers) from Earth.

Venus

Venus is now a gleaming bright object in the west after sunset. During the month of March, it will climb steadily in altitude each night at about the same rate as it progresses northward along the horizon.

In a telescope, you can see that Venus' apparent disk is becoming noticeably less round and more like a gibbous Moon. As it overtakes Earth in its orbit around the Sun, Venus shows us more and more of its unlit side. By early June — about the time of maximum elevation — the disk will be half lit.

In the evenings of March 15th and 16th, a slender crescent Moon will join first Mars (on the 15th) and then Venus (the next night) to make a fine conjunction. The separation between the objects is too great to squeeze them into the field of even a low-power eyepiece, but try scanning back and forth between them — you'll find the view very pretty.

Earth

The Sun passes northward across the celestial equator at 4:39 UT on the 21st; this marks the vernal equinox and beginning of spring for the northern hemisphere. The Sun will remain north of the celestial equator for 186 days 10 hours 3 minutes — until September 23rd at 14:42 UT, the moment of the autumnal equinox.

A broad swath of luminous hydrogen gas, NGC-1499 — better known as the California Nebula — lies near the fourth-magnitude star Xi (ξ) Persei. Rick Dilsizian photographed it with an 8-inch Schmidt camera, hypered 2415 film, and a 12-minute exposure — and won this month's "Best Astro-Photo" award.

Mars

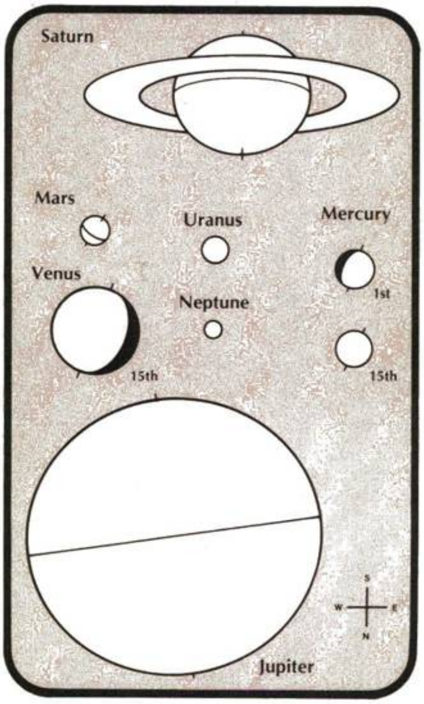
Mars is faint, distant, and small, and its elevation in the western sky is dropping steadily lower each evening. In a telescope it is a disappointment. In any case, it will be lost in the glare of twilight before many more weeks have passed.

Asteroids

1 Ceres (magnitude 8.8) is moving eastward in western Capricornus. Its positions:

10th: 20h 33m 25s, -23° 19.1′
20th: 20h 50m 25s, -22° 47.3′

Ceres rises about 5 a.m. local time in the middle of the month.



2 Pallas (10.0) lies in northeastern Ophiuchus/western Aquila. Its positions:

10th: 18h 49m 11s, + 9° 24.5′
20th: 18h 58m 27s, +10° 50.7′

Pallas rises around 1 a.m. local time on the 15th.

3 Juno (10.5) is moving eastward in central Aquarius. Its positions:

10th: 21h 59m 00s, -7° 19.3′
20th: 22h 16m 15s, -6° 02.1′

Juno rises around 5 a.m. local time on the 15th.

4 Vesta (8.2) lies in northwestern Cetus. Its positions:

10th: 0h 37m 33s, −1° 36.5′
20th: 0h 54m 24s, +0° 15.1′

Vesta, in conjunction with the Sun on April 14th, sets about 7:30 p.m. local time at mid-month.

(To facilitate plotting their positions on a star atlas, all asteroid coordinates are for the epoch 2000.0.)

Jupiter

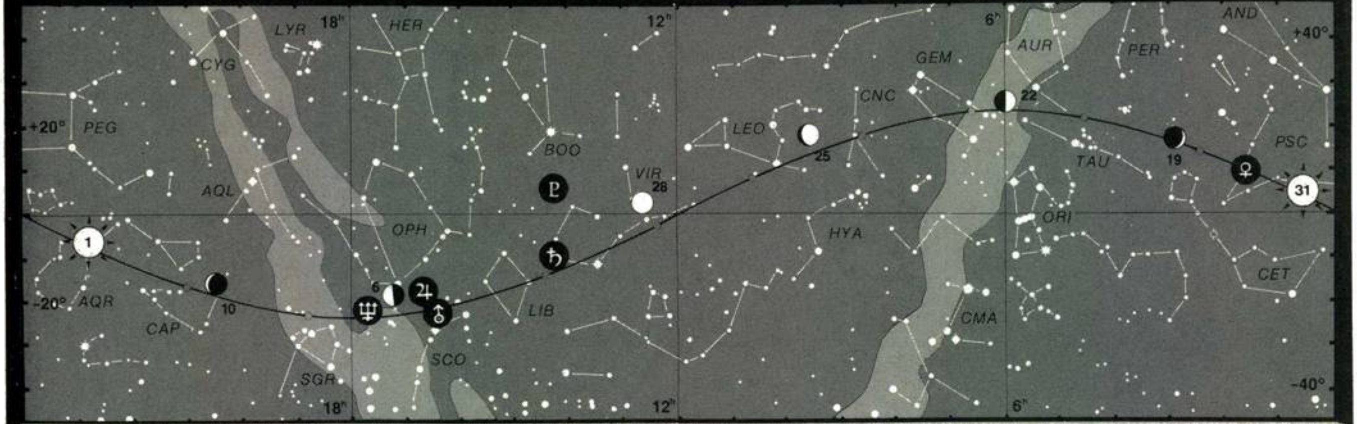
Jupiter will be visible low in the east-southeast by an hour after midnight. If staying up late doesn't appeal to you, try getting up an hour or two before sunrise — you'll easily find Jupiter in the southern part of the sky among the stars of Scorpius.

Many reference books tabulate Jupiter's rotation period simply as 9h 50m. But if you train your scope on the planet's "surface" features — which are really the tops of clouds — and make very careful observations and timings with a stop watch, you'll discover that Jupiter has two rotation periods. (In fact, there is even a third period, revealed by radio observations.)

The commonly listed figure for the period actually refers to system 1, the rotation period of the region between and including the North and South Equatorial Belts. Another rotation period, system 2, covers the rest of the planet. System 1 rotates once every 9h 50m 30s; system 2 takes 9h 55m 41s. (The radio emission period, system 3, lasts 9h 55m 29s and probably corresponds to the rotation of Jupiter's rocky core.) The result of the small discrepancy between systems 1 and 2 is that you can see equatorial features gaining slowly on those in the middle latitudes.

Try to find a feature in the equatorial region and another in the middle latitudes; compare how they move across the face

planetary data march 1983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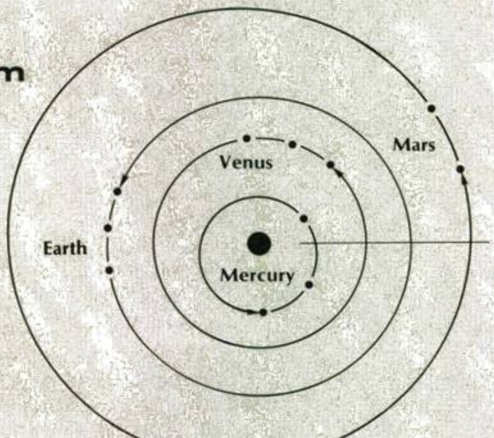
inner solar system


Venus
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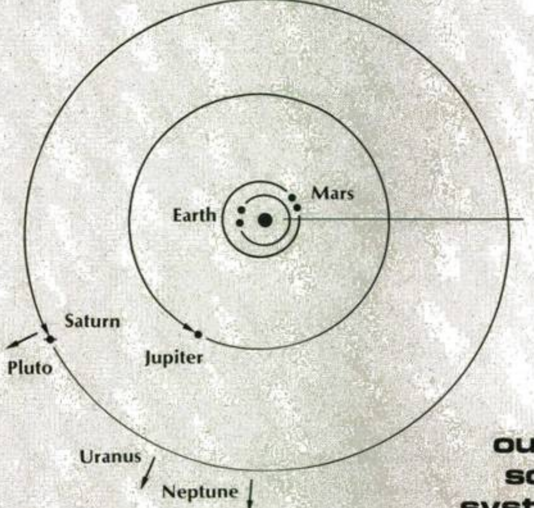

Mars
Earth
Saturn
Pluto
Jupiter
Uranus
Neptune

outer solar system

		Date	Mag.	Angular Size	% Illum.	Distance (AU) from: Earth	Distance (AU) from: Sun	Longitude: Heliocentric	Longitude: Ecliptic	R.A. (1983.3)	Dec.
Sun		1	−26.8	32.3′	—	0.99	—	—	339°50.3′	22h 45.5m	−7°53.1′
		15	−26.8	32.2′	—	0.99	—	—	353°50.7′	23h 37.4m	−2°26.9′
		31	−26.7	32.1′	—	1.00	—	—	9°43.2′	0h 35.7m	+3°50.9′
Mercury	☿	1	−0.1	5.3″	85%	1.25	0.46	273°51.7′	319°47.3′	21h 32.9m	−16°30.5′
		15	−0.7	5.0″	95%	1.35	0.41	317°22.0′	343°00.6′	23h 02.1m	−8°30.3′
		31	−1.6	5.1″	98%	1.31	0.33	29°08.7′	14°00.6′	0h 54.1m	+5°10.1′
Venus	♀	10	−3.4	12.1″	87%	1.39	0.72	61°33.5′	18°05.1′	1h 09.1m	+6°50.8′
		31	−3.5	13.2″	81%	1.27	0.72	95°25.5′	43°30.4′	2h 45.3m	+16°37.6′
Mars	♂	15	+1.5	4.0″	99%	2.32	1.43	27°31.9′	13°19.2′	0h 51.4m	+5°02.6′
Jupiter	♃	15	−1.8	38.9″	99%	5.06	5.37	240°17.1′	250°10.7′	16h 36.8m	−21°09.8′
Saturn	♄	15	+0.6	18.6″	100%	8.98	9.76	209°54.8′	213°11.0′	14h 09.4m	−10°12.5′
Uranus	♅	15	+5.9	3.8″	100%	18.66	18.93	246°12.2′	248°32.5′	16h 29.7m	−21°42.8′
Neptune	♆	15	+7.8	2.5″	100%	30.34	30.27	267°17.0′	268°37.5′	17h 56.3m	−22°12.3′
Pluto	♇	15	+13.8	0.1″	100%	29.12	29.90	207°54.2′	208°33.0′	14h 12.5m	+5°13.1′

moon data

Last Quarter	March 6 at 13:16
New Moon	March 14 at 17:43
First Quarter	March 22 at 2:25
Full Moon	March 28 at 19:27
Last Quarter	April 5 at 8:38
New Moon	April 13 at 7:58
Apogee: March 9 at 23h	405,371 km.
Perigee: March 25 at 22h	365,418 km.

universal time

Astronomers the world over use an unambiguous system of time reckoning — Universal Time (UT) — based on a 24 hour clock. Times in The Backyard Astronomer are UT unless otherwise noted. To convert UT into your local standard time, subtract the following number of hours for each time zone: EST, 5; CST, 6; MST, 7; PST, 8; Alaska and Hawaii, 10. For example, if an event is to happen at 03:00 hours UT on February 2, then EST for the event is 10 p.m., February 1. Likewise, 03:00 UT on March 5 becomes, in PST, 7 p.m, March 4.

Located in Canes Venatici about 10° northwest of Arcturus, the globular cluster M-3 packs over 45,000 stars into a tight ball about 10′ of arc across. Clive Gibbons took its photograph with an 8-inch S-C telescope at f/7.6 (using a focal reducer) in a 55-minute exposure on 400 ASA film pushed to 800 ASA.

of Jupiter. Can you detect the difference in rotation rate?

Saturn

Saturn rises around 9:30 p.m. local time in the middle of March; you won't have to wait until late in the evening or get up early in the morning to see it. Located in Virgo, the planet is easy to spot, being the brightest object between Spica and Antares.

Like Jupiter, Saturn has three rotation systems — but they are far more difficult to observe due to the faintness of all saturnian markings. Saturn's system 1 includes the North and South Equatorial Belts and the zone between them; system 2 is everything else. (The radio emission of system 3 probably corresponds, as with Jupiter, to the planet's solid-body rotation.) System 1 has a period of 10h 14m 13s, system 2 has 10h 38m 25s, and system 3 has 10h 30m — but even more than with Jupiter, these figures are average values. See what you can derive on your own!

Uranus

During March, Uranus rises a little after midnight, and is nearly stationary against the background of the stars of Ophiuchus. Its position is easy to find, however, because it lies about 30′ southwest of the 4.5 magnitude star Omega (ω) Ophiuchi. This is also 4½° north and a little east of Antares. When you find the region, switch to a medium-power eyepiece and start looking for the sixth-magnitude "star" that has a visible disk.

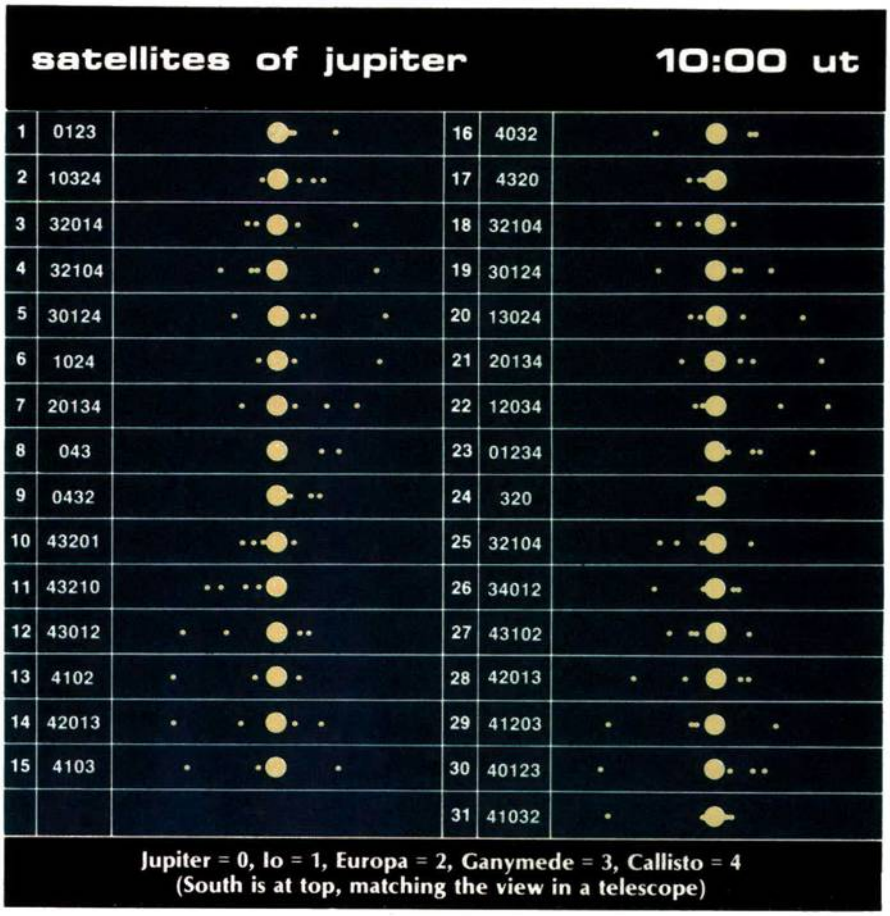
Neptune

To locate Neptune, start around 3:30 a.m. local time by finding the Trifid Nebula, M-20, in Sagittarius. Then sweep your scope a degree north and about 5 minutes of right ascension (1¼°) west. You can spot Neptune by its eighth-magnitude disk, 2.4″ across.

Pluto

Around the 20th of March, Pluto will pass beside an eighth-magnitude double star in Virgo, SAO 120348/9. Although it is in conjunction with the star (in right ascension) on the 14th, Pluto's motion will keep it nearby for at least another week or 10 days. This double star is plotted on chart 14 of the *Sky Atlas 2000.0*, 23 millimeters above and 2 mm to the left of the star CU Virginis near the center of the chart.

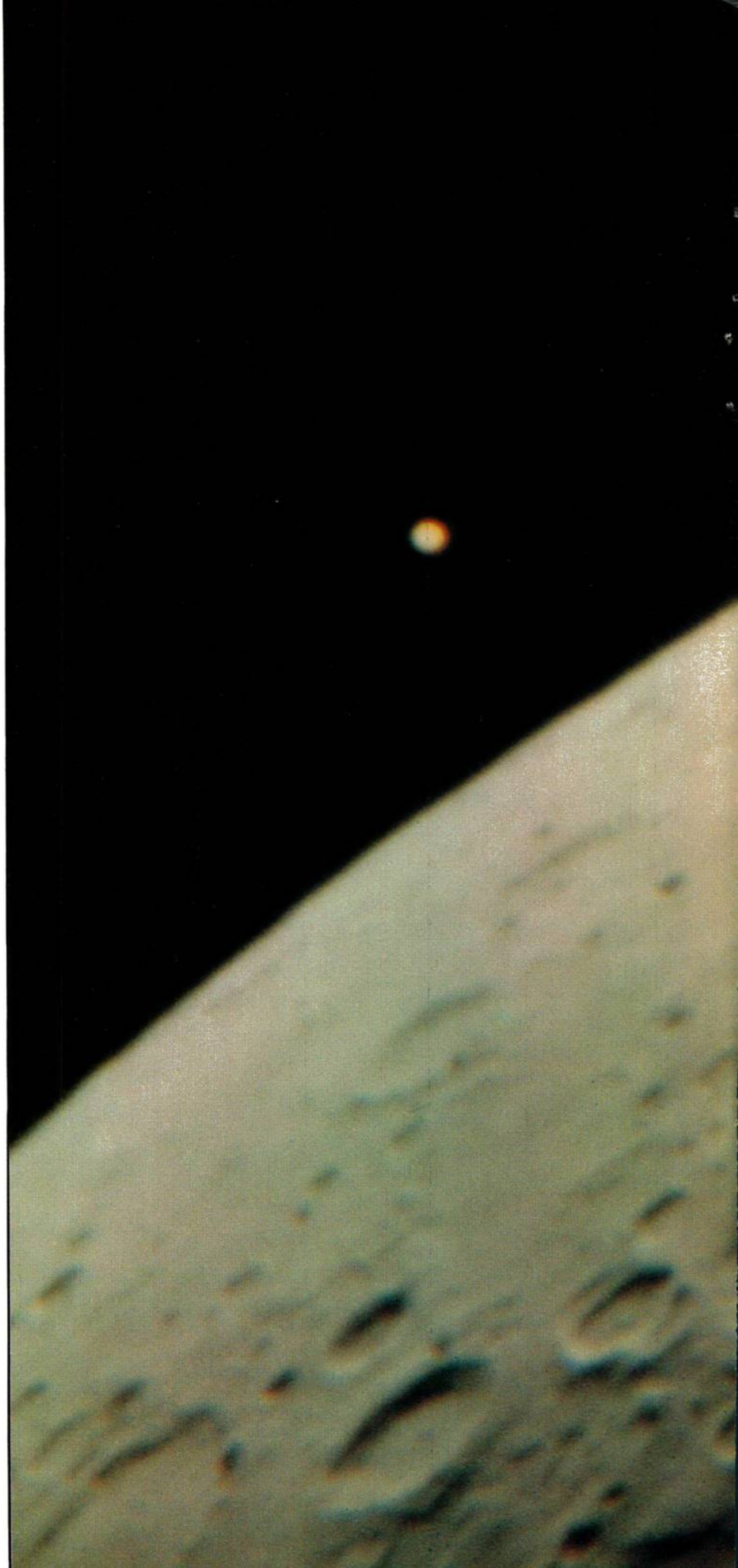
How do you identify Pluto? Find the region and plot with pencil and paper the position of the stars you see. Look again the next night or so; the star that moved is Pluto. Alternately, you could photograph the region on two or more nights and compare the images.



satellites of jupiter 10:00 ut

1	0123
2	10324
3	32014
4	32104
5	30124
6	1024
7	20134
8	043
9	0432
10	43201
11	43210
12	43012
13	4102
14	42013
15	4103
16	4032
17	4320
18	32104
19	30124
20	13024
21	20134
22	12034
23	01234
24	320
25	32104
26	34012
27	43102
28	42013
29	41203
30	40123
31	41032

Jupiter = 0, Io = 1, Europa = 2, Ganymede = 3, Callisto = 4
(South is at top, matching the view in a telescope)



The conjunction/occultation of Mars and the Moon on November 19, 1982 was photographed by Donald Parker from Coral Gables, Florida. The photo, taken at 23:03 UT, was made with a 12½-inch Newtonian (and eyepiece projection to f/52) on 200 ASA film in a 3-second exposure.

close-up on puppis

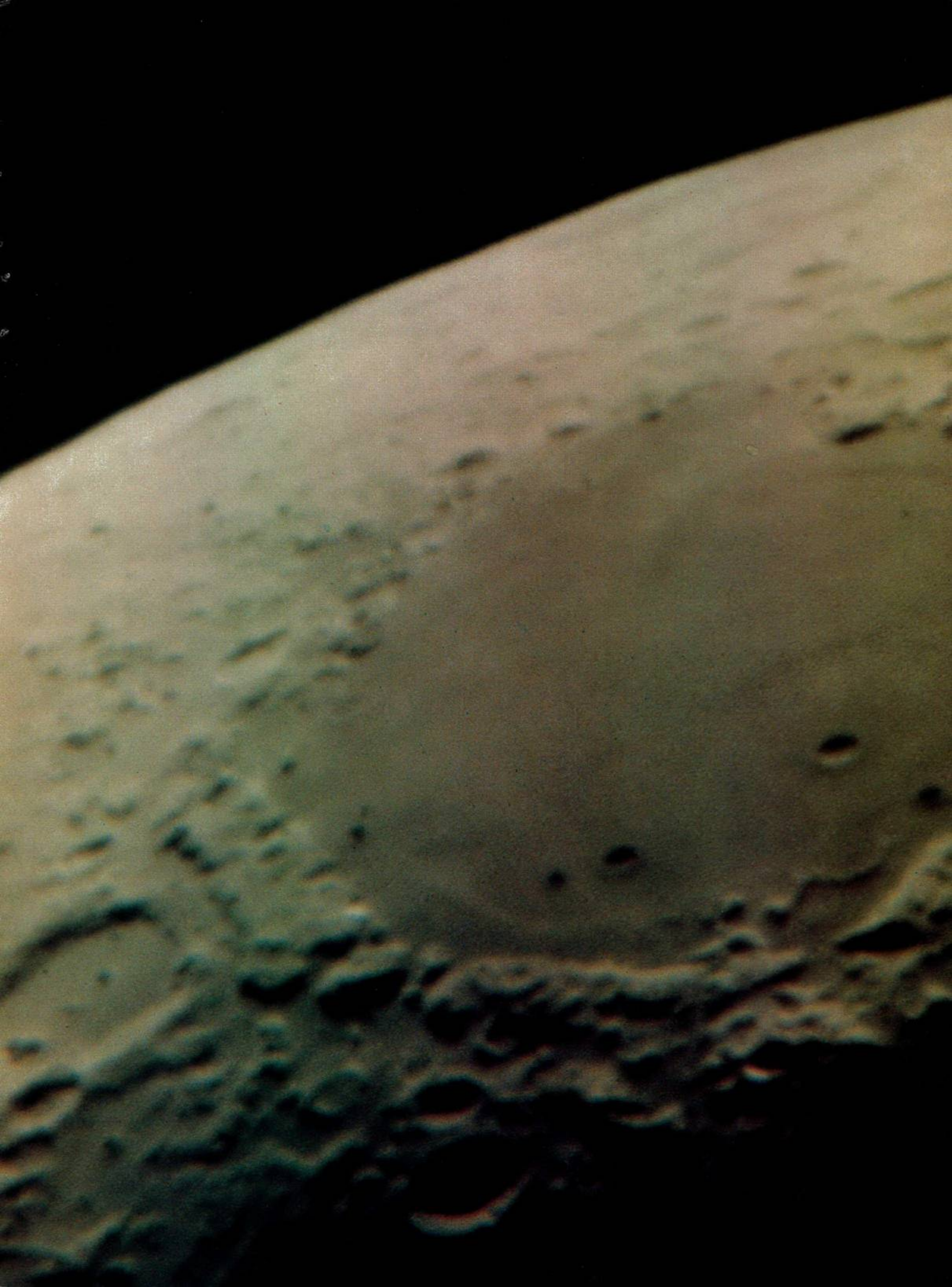
For the last two months, we've looked at winter Milky Way areas heavily laden with bright open star clusters and enveloped in wispy emission and reflection nebulosity — the constellations Orion and Canis Major. Following the Milky Way still farther south, we encounter the constellation **Puppis**, also rich in bright open clusters, interesting stars, and strange nebulae. Here we can even find a slightly out-of-place globular cluster.

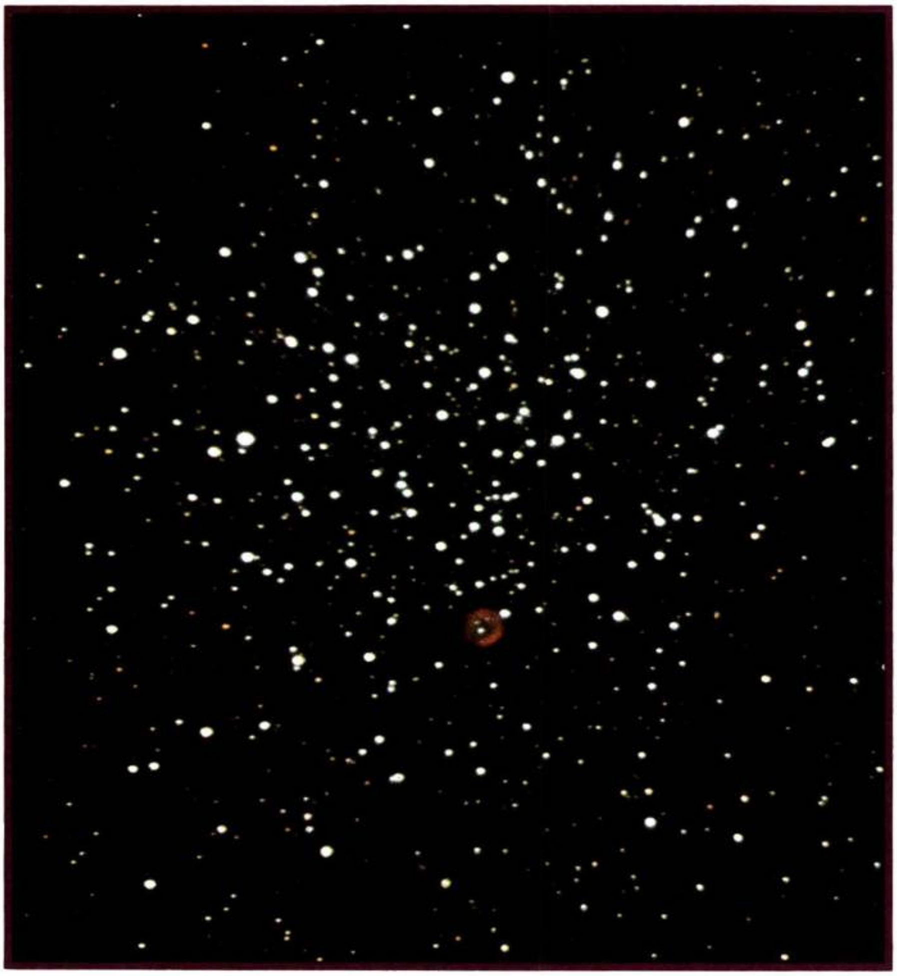
One of the most interesting objects in the region is the open star cluster **M-46**, a large rich group that packs 150 stars of magnitudes 10 to 13 into an area nearly as large as that of the Full Moon. At magnitude 6.5, it's a bright object: try observing M-46 with a low-power, wide-field ocular on a dark night. With a telescope of 4- to 8-inch aperture, you'll be delighted with the view of dozens of faint stars clumped together. You'll also notice a faint fuzzy patch on the northern edge of the cluster. This is **NGC-2438**, a near-duplicate of the Ring Nebula in Lyra, but slightly smaller and fainter. It is a fascinating sight at high magnification; the ring-shaped wisp of smoke appears to float among many pinpoints of light.

NGC-2438 is actually completely unassociated with the group of stars. Astronomers estimate that the cluster is nearly 5,000 light-years away; the nebula is about 3,000 light-years distant. If these figures are correct, the diameter of the cluster is roughly 30 light-years — a giant compared to the one light-year width of the nebula.

Although they are not associated, the two combine to make a challenging eyepiece target. Observers with large telescopes — 12-inch to 20-inch aperture — under superb seeing conditions have the chance of spotting the elusive 16th magnitude central star embedded in NGC-2438. This is certainly no easy task, however, especially since the nebula is surrounded by so many cluster stars.

Just 1.5° away from M-46 is a much brighter Messier cluster, **M-47**. This group is made up of 45 stars that combine to give it a magnitude 4.5 glow, so it is a spectacular binocular object. The bright glow of M-47 and the soft fuzziness of M-46 offer a nice contrast in binocular fields, although it is difficult to spot the planetary nebula without telescopic aid. M-47 is slightly larger than M-46, at 30', and is best observed with low power in





An open cluster that appears to harbor a planetary nebula within itself, M-46 is a bright and easy-to-observe showpiece; it is discussed in this month's Close-up on Puppis. Bill Iburg photographed it with a 14-inch S-C scope at f/5.5 (using a focal reducer) in a 30-minute exposure on 400 ASA film with a cold camera.

6- to 10-inch telescopes.

NGC-2423 is a loose seventh-magnitude open cluster that lies less than a degree north of M-47. Its 80 stars of around 12th magnitude are clustered in a 20′ diameter, and it is best observed with a wide-field eyepiece. Interestingly, NGC-2423 is much older than either nearby Messier cluster — hence it is looser and contains less energetic stars. M-46 and M-47 are both about 20 million years old; NGC-2423 is a whopping 300 million years old.

Another interesting open cluster is **M-93**, a group of about 100 suns tightly packed into only 12′ of sky. It is a "versatile" deep-sky object — it looks good in almost any telescope — and shines at an integrated magnitude of 6.5. Locate M-93 with low power, then switch to about 20x per inch of aperture. You should note the triangular shape of the cluster — it is almost reminiscent of M-11 in Scutum.

Only 3° southeast of M-93 is a strange nebula designated **NGC-2467**, a small clump of emission nebulosity around an eighth-magnitude star. The nebula spans 12′, but only a small portion of it is observable with backyard instruments. In an 8-inch reflector under excellent seeing, perhaps 2′ of fuzz is visible, but the object is by no means impressive. Observers who have large — say, 20-inch — reflectors can probably see this nebulosity fairly easily.

Yet another bright open cluster lies far to the south. If a good horizon is available, it should be a fantastic sight. **NGC-2477** measures only 20′ in diameter, but contains 300 stars and shines at magnitude 5.5 — thus it can be seen with the naked eye on dark nights. Medium magnifications yield the most pleasing view of this cluster, which is more impressive than M-46. NGC-2477 is almost twice as far as M-46; placed at the same distance, 2477 would outshine the Messier cluster by a wide margin. It is odd that Messier didn't record this group in his famous catalog of nebulous objects, but it was undoubtedly too far south to concern him.

A final bright open cluster in Puppis is **NGC-2546**, a group of about 50 stars of ninth magnitude in a 25′ diameter. The group shines at fifth magnitude, but it is relatively hard to see because it is nearly as far south as NGC-2477. As with 2477, wait until a good dark night, find a good southern horizon, and use medium powers.

The lone globular cluster in the area is **NGC-2298**, an object that shines through Milky Way obscuration at magnitude 10.5. The little ball of stars is only 3′ across. It is recognizable as a globular in most telescopes, but is not an impressive target.

Interesting stars abound in the constellation Puppis. **V Puppis** is an eclipsing binary — a star that behaves like the prototype, β Lyrae — and lies far in the southern reaches of the constellation. The system is composed of two B-type giant stars that are nearly in contact with each other, and revolve in a period of 1.45 days (or 34h 54m). Since their orbit is inclined 15° to our line of sight, both stars eclipse one another during an orbit. The star system appears to be magnitude 4.7 at its brightest and drops 0.6 magnitude at its dimmest.

Sigma (σ) **Puppis** is a fine binary star, with unequal components of magnitudes 3.3 and 8.5 moving in a common proper motion. The two stars offer a fine display of color — the brighter is orange, and the fainter is white-yellow. The pair lies 180 light-years away, so their 22.4″ apparent separation means an actual distance of 1,200 astronomical units. The secondary, lying at position angle 74°, appears much as our Sun would from its distance. When you peer into the eyepiece, imagine a system with an enormous, K-type star and a smaller one like our Sun.

Something funny happened to the star **CP Puppis** in 1942 — it went nova. Ever since, astronomers have carefully monitored its behavior, hoping to find details of the nova process. Before the catastrophic event, the star was imperceptibly dim — it wasn't recorded on photos that probed down to 18th magnitude. But on November 8, 1942, it erupted in a 15 million-fold jump in brightness that brought it to near magnitude 0. Shortly thereafter it dimmed again and, in early 1982, was around magnitude 14.2. Even such a dim star *is* fascinating because of the awesome event that it displayed for the rest of the Galaxy. According to Robert Burnham, Jr., if the Sun underwent such an event, the Earth's crust would almost instantly be reduced to a depth of 12 miles!

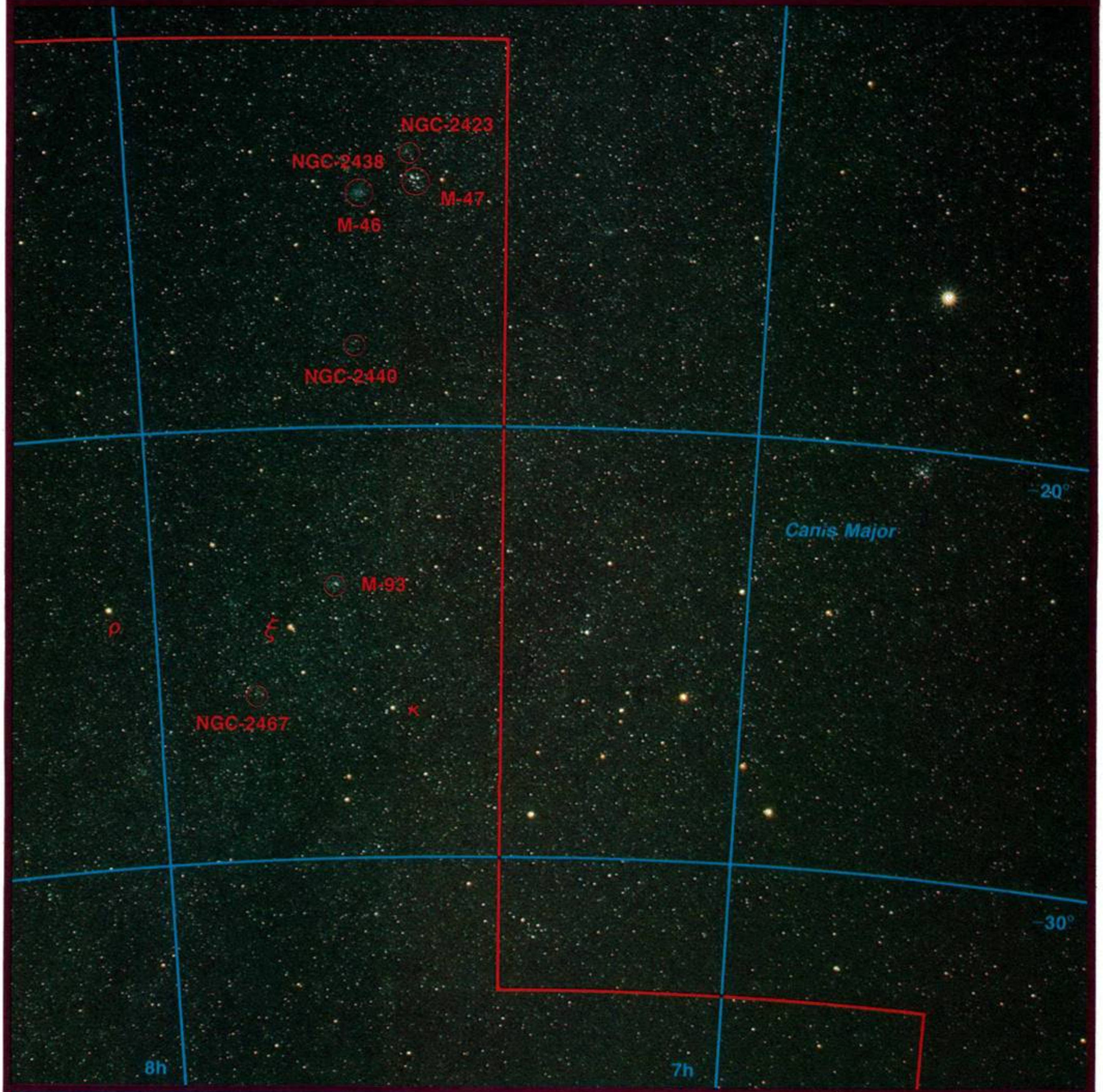
Zeta (ζ) **Puppis** is one of the most luminous known stars in our Galaxy. It shines at magnitude 2.3, and lies about 2,400 light-years away. At this distance, calculations state that it is 60,000 times more luminous than the Sun; if it were as close as Vega (27 light-years), it would glow a dozen times brighter than the planet Venus.

A varied bunch of celestial showpieces await you and your telescope in the constellation Puppis. With a good star atlas, a telescope and wide field eyepiece, dark skies, and a little effort, you can seek out the Milky Way treasures in a little-observed region that contains a handful of unique, intriguing stars and clusters.

photo by Brad Wallis & Robert Provin

puppis

map by Robert Burnham



Object	Type	Mag.	Size/Sep. Per.	R.A. (1950)	Dec.	R.A. (200)	Dec.
NGC-2298	●	10.5	3′	06h 47m	−35°57′	06h 49m	−36°00′
Sigma (σ)	★^{2}	3.3+8.5	22.4″	07h 28m	−43°12′	07h 29m	−43°18′
M-47	⊙	4.5	30′	07h 34m	−14°22′	07h 37m	−14°29′
NGC-2423	⊙	7.0	19′	07h 35m	−13°45′	07h 37m	−13°52′
M-46	⊙	6.5	27′	07h 40m	−14°42′	07h 42m	−14°49′
NGC-2438	■	11.5	68″	07h 40m	−14°36′	07h 42m	−14°43′
NGC-2440	■	11.5	50″x20″	07h 40m	−18°05′	07h 42m	−18°12′
M-93	⊙	6.5	13′	07h 42m	−23°45′	07h 45m	−23°52′
NGC-2477	⊙	5.5	25′	07h 51m	−38°25′	07h 52m	−38°33′
NGC-2467	□	7.0	12′	07h 51m	−26°16′	07h 53m	−26°24′
V	EV	4.7-5.3	1.5d	07h 57m	−49°07′	07h 58m	−49°15′
Zeta (ζ)	★	2.3	—	08h 02m	−39°52′	08h 04m	−40°00′
CP	★	14.2	—	08h 10m	−35°12′	08h 12m	−35°21′
NGC-2546	⊙	5.0	25′	08h 10m	−37°32′	08h 12m	−37°41′

★	*Star*
★^{2}	*Double Star*
★^{3}	*Triple Star*
RV	*Regular Variable*
IV	*Irregular Variable*
EV	*Eclipsing Variable*
⊙	*Open Cluster*
●	*Globular Cluster*
■	*Planetary Nebula*
□	*Bright Diffuse Nebula*
0	*Elliptical Galaxy*
§	*Spiral Galaxy*
∮	*Barred Spiral Galaxy*
#	*Peculiar/Irregular Galaxy*

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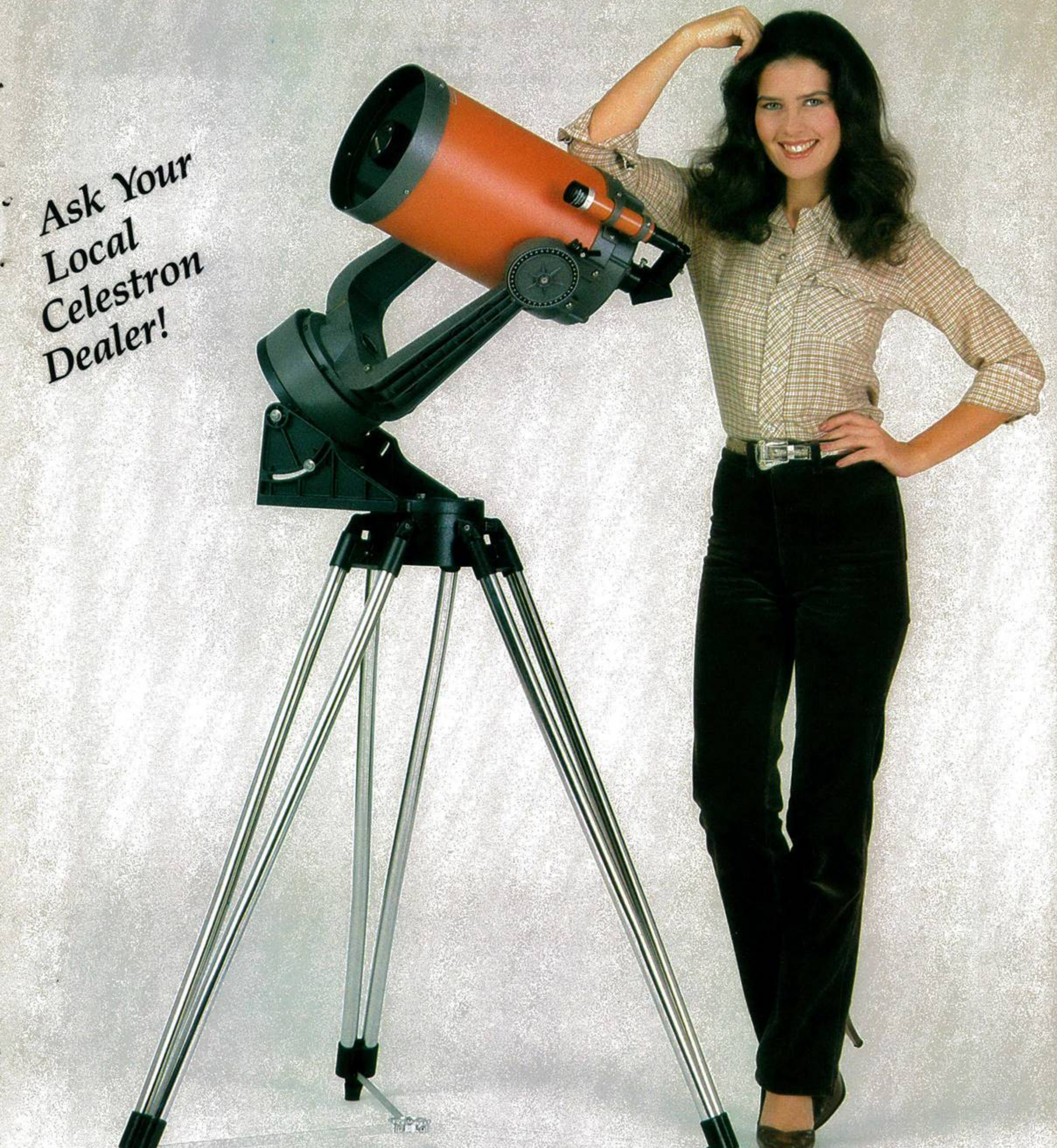
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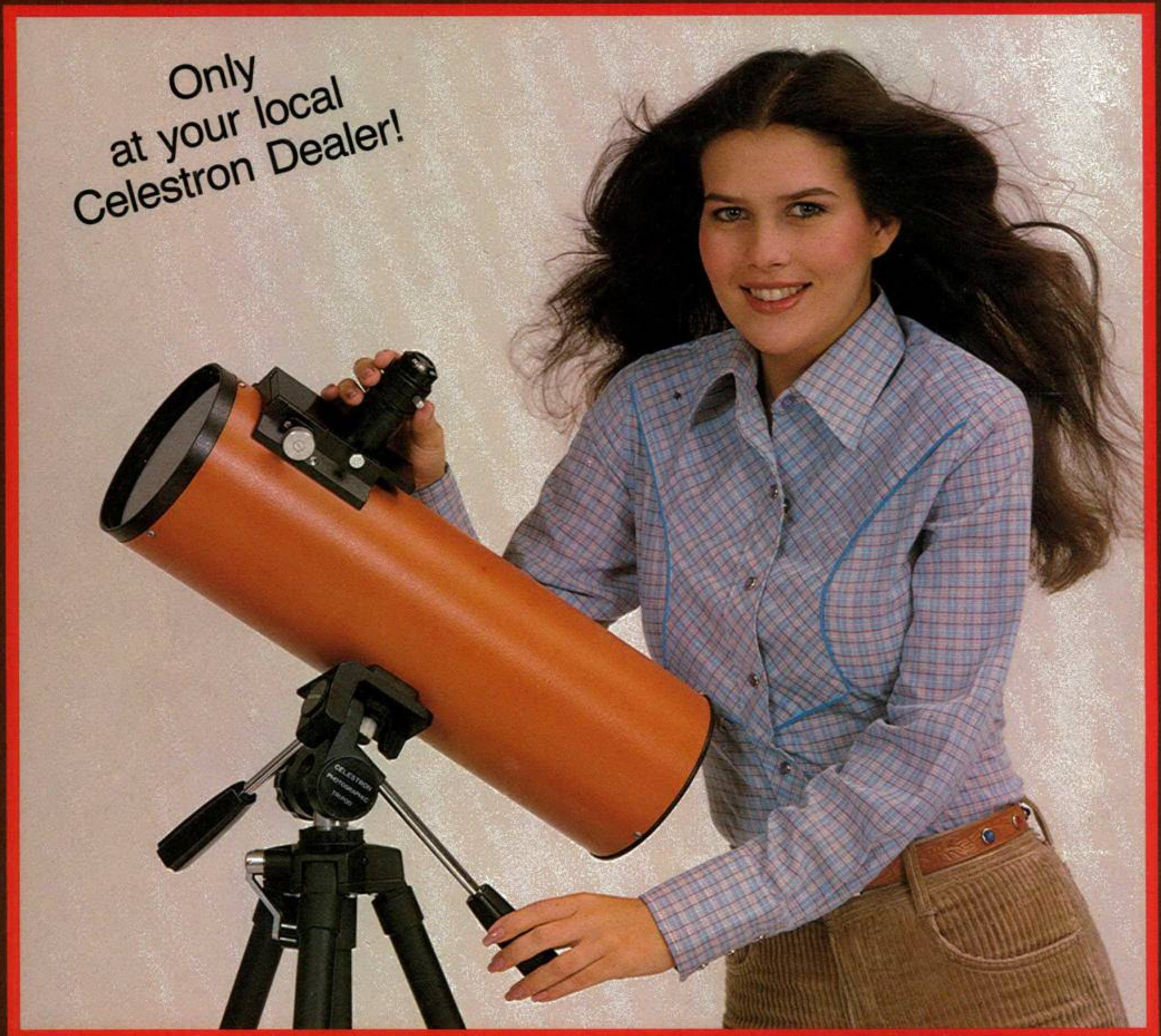

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